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Transactions of the Academy of Science of St. Louis

Volume XXV, No. 1

O. K.

THREE NEW SPECIES OF TEREDO

W. F. CLAPP

Issued April, 1924

THREE NEW SPECIES OF TEREDO.

W. F. Clapp.

The material from which the following descriptions were drawn, was removed from test-blocks of wood placed in the water by the Committee on Marine Piling Investigations of the National Research Council. For descriptions of the test-blocks, and also for notes regarding the nomenclature used in the descriptions of the various characters of the shell and pallets, and for references to recent literature on the subject, consult Clapp, 1923, Proc. Bos. Soc. Nat. Hist., vol. 37, no. 2, pl. 3-4, p. 31-38, text fig. 1.

I am deeply indebted to Prof. S. C. Prescott of the Massachusetts Institute of Technology, Cambridge, Mass., for laboratory facilities and for other assistance.

TEREDO (TEREDO) PORTORICENSIS SP. NOV.

Plate I, figs. 1-7.

Shell subglobular, white, covered with a transparent, colorless periostracum. The juncture of the anterior with the anterior-median area clearly marked by a broadly curved, slightly incised line. The ventral edge of the anterior area, forming an angle of about 100° with the anterior edge of the anterior-median area. Externally, the anterior area with the usual denticulate ridges, the ventral posterior portion, with the ridges of about one-half the width of the intervening spaces. Dorsally the ridges are only one-fourth as wide as the spaces between them. Beginning at the ventral posterior edge, there are eight of these ridges to the millimeter, each ridge bearing approximately seventy denticles to the millimeter (fig. 1). The anterior-median area, at a point opposite the ventral edge of the anterior area, is one-quarter of the width of the entire median area. The denticulate ridges on this area, in a line continuous with the ventral edge of the anterior area, average twenty-five to the millimeter. In the type there are eleven of these ridges, which bear the usual broad denticles, there being twenty-eight denticles to the millimeter (fig. 2). The ventral ends of these ridges can be clearly seen continuing as sharp growth lines over the entire median area, but becoming less distinct on the auricle. The middle-median area is milk-white, in contrast to the semi-transparent anterior-median area, and is separated from the anterior-median area by a thin, narrow, transparent band. The posterior-median area is milk white and occupies one-half of the entire median area. The auricle is semi-transparent, showing more or less irregular growth lines, and the periostracum is here thicker than elsewhere on the shell.

Internally, in the left valve a short, broad, flat hinge plate, directly beneath the umbone. The blade slightly more than one-half the length of the shell, of nearly uniform width for its entire length, the lower half reflected posteriorly. The ventral knob large. The internal shelf of the auricle well marked.

Pallets (fig. 3) of the type of *Teredo navalis* Linné. The stalk of about the same length as the blade, and merging into it by a gradual curve. The lower half of the blade white, the calcareous part of the upper half, as seen through the transparent chitinous covering, slightly cupped, the lateral portions extending farther distally than the median. The upper half entirely composed of transparent, yellowish horn-colored periostracum, which is deeply cupped distally for more than half its length, the outer surface being slightly less deeply cupped than the inner, and with a deep, narrow sinus at the center.

The posterior end of the tube with two short, narrow, low ridges arising from opposite sides of the internal wall; these ridges continue posteriorly beyond the shelly portion of the tube as sharp points.

The type specimen (Mus. Comp. Zoöl., 45303) is from San Juan, Porto Rico. Additional specimens from the type locality are also in the U. S. National Museum.

The measurements of the type are:

Total length of tube 40 mm.

Shell, height 3.2 mm., length 3.1 mm.

Pallets, length 3.8 mm., divided equally between blade and stalk, width of blade 0.8 mm.

Teredo portoricensis is more closely related to *Teredo bartschi* Clapp than to any other described species. The variation of the shell characters in each species is so great that only very slight constant differences can be seen. The normal shell of a mature specimen of *T. portoricensis* is smaller than that of *T. bartschi.* The length of the apophysis always proportionately less. The partitions in the tube, while always present, are much lower and shorter than in *T. bartschi.* The pallets resemble those of *T. bartschi,* but constantly differ from them in having the blade longer and narrower, the juncture of the blade and pallet hardly perceptible, and the basal portion of the blade more gradually expanded. Seen through the periostracum, the calcareous portion of the blade of the pallet of *T. bartschi* appears cone shaped, whereas that of *T. portoricensis* is the opposite, being deeply cupped at the center. In *T. portoricensis* the periostracum on the outer face of the blade is less deeply cupped than that on the inner, while in *T. bartschi* the reverse is true.

This species has been found in the test-blocks placed by the Committee on Marine Piling Investigations, at the following locations: Guantanamo, Cuba; San Pedro de Macoris, Santo Domingo; Port au Prince, Haiti; San Juan, Porto Rico; St. Thomas, Virgin Islands; Coco Solo, Panama, and (one specimen) Key West, Florida.

At Guantanamo, Cuba, wood placed in the water on April 10th, contained specimens 10 mm. in length on May 10th; 60 mm. in length on June 10th, and 75 mm. in length July 10th.

At Port au Prince, Haiti, wood submerged December 1, 1922, contained on January 1, 1923, many 5 mm. specimens; on January 15th, 30 mm. specimens, and on February 1st, 30 mm. specimens with the gills well filled with many fully developed embryos. Wood placed in the water at this location on June 1, 1923, although well filled with several other species of shipworms, contained no specimens of *T. portoricensis* as late as September 3, 1923.

At San Pedro de Macoris, Santo Domingo, wood submerged December 1, 1922, contained 20 mm. specimens on February 1, 1923, many of them with well-developed embryos.

At San Juan, Porto Rico, wood placed March 20, 1923, contained on May 30th, *T. portoricensis* 40 mm. long with embryos.

At St. Thomas, Virgin Islands, wood placed April 1, 1923, contained many 30 mm. specimens on June 1st.

At Coco Solo, Panama, wood submerged December 4, 1922, contained many 30 mm. specimens on January 19, 1923, and on February 19th, many specimens with well-developed embryos in the gills.

It can be seen from the above records that this species may grow to be 60 mm. in length in a period of two months, or at the rate of approximately 1 mm. a day, and that specimens with a total tube length of but 20 mm. may possess well-developed embryos within the gills. Its rapid growth and early sexual maturity render it one of the species most frequently found in the West Indies, and the destruction caused by it is considerable.

EXPLANATION OF PLATE

PLATE I

(All figures reduced $\frac{8}{16}$)

Teredo portoricensis

Fig. 1. Denticulate ridges of the anterior portion. x 100.
Fig. 2. Denticulate ridges of the anterior-median portion. x 100.
Fig. 3. Pallets. x 14.
Fig. 4. Exterior of right valve. x 14.
Fig. 5. Exterior of left valve. x 14.
Fig. 6. Interior of left valve. x 14.
Fig. 7. Interior of right valve. x 14.

FIG. 1

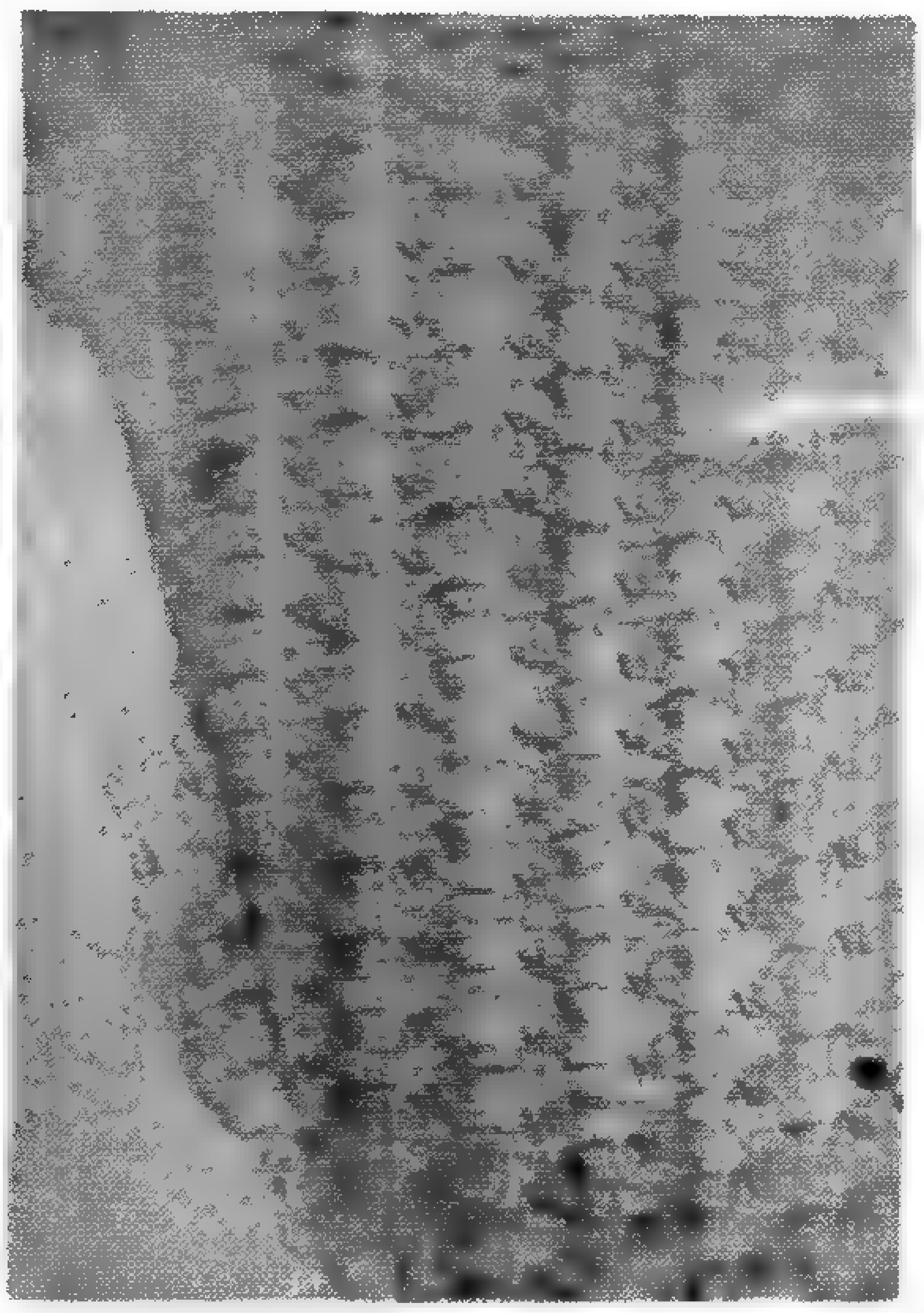

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

TEREDO (ZOPOTEREDO) JOHNSONI* SP. NOV.

Plate II, figs. 8-15.

Shell subglobular, white, covered with a thin, nearly transparent, colorless periostracum. The narrow incised line separating the anterior and the anterior-median areas very slightly curved. The ventral edge of the anterior area meeting the anterior edge of the anterior-median area in a nearly straight line, forming an angle of approximately 90°.

Externally, the anterior area large, with many evenly spaced, denticulate ridges, which are of about the same width as the intervening spaces. There are sixteen of these ridges to the millimeter on the posterior-ventral portion of this area, each ridge bearing one hundred and twenty minute denticles to the millimeter (fig. 8). The anterior-median area occupying, at its widest part, one-third of the entire median area. The denticulate ridges on this area, along a line continuous with the ventral edge of the anterior area, average thirty to the millimeter. There are twenty-six of these ridges in the type specimen, each ridge bearing approximately thirty-three denticles to the millimeter (fig. 9). The middle-median area is narrow, divided longitudinally into nearly equal halves, the anterior half, with the continuation of the denticulate ridges, showing as narrow, diagonally descending growth lines, which curve upward, and become more or less obscure on the posterior half of the middle-median area. The posterior-median area large, occupying more than half of the entire median area, nearly smooth, showing only occasional, faint, incised growth lines. The auricle very small, being merely a continuation of the

*I take pleasure in naming this species for Mr. A. A. Johnson, Assistant to the Director of the Marine Piling Investigations Committee of the National Research Council.

posterior-median area, with no trace externally of a separating groove or concavity.

Internally, a small, square hinge-plate in the left valve. The blade two-thirds of the length of the entire shell, thin, broad dorsally, the middle and ventral portions narrower, its entire length reflected slightly posteriorly. The ventral knob narrow, long, its base extending dorsally for a considerable distance. The juncture of the anterior with the anterior-median area marked by a narrow, thickened chord. The juncture of the auricle with the posterior-median area hardly visible.

Pallets (fig. 10) with long, stout, opaque white stalks. The blade short, broad, investing a considerable portion of the upper part of the stalk in a thin sheath. The outer face convex. The proximal third of the blade calcareous, arising from the stalk in an abrupt curve. The middle third swollen, covered with a light horn-colored periostracum. The distal third covered with a dark chestnut colored periostracum with a deep central sinus dividing this portion of the blade into two shallow cups, the outer face considerably more deeply indented than the inner. The inner face of the blade flat, its distal two-thirds covered with a periostracum irregularly streaked with narrow bands of light and dark chestnut.

The posterior end of the tube with a long delicate partition (fig. 11) dividing the tube into equal parts.

The type (Mus. Comp. Zoöl., 45306) is from Guantanamo, Cuba.

The measurements of the type are:

Shell, height 4.5 mm.; length 4.5 mm.

Pallets, total length 4.3 mm.; length of stalk 3 mm.; width of blade 1.6 mm.

The shell of this species is very closely related to that of *Teredo clappi* Bartsch (Proc. Biol. Soc. Washington, 1923, 36, p. 96). However the apophysis is shorter and narrower, the ventral knob smaller. The entire median area in *Teredo johnsoni* is always proportionately broader than in *Teredo clappi*. The range of variation of the denticulate ridges of both species is so great that no constant difference can be established, but the angle formed at the juncture of the ridges of the anterior area with those of the anterior-median area is always approximately 90° in *Teredo johnsoni* whereas, in *Teredo clappi* it is constantly obtuse, being rarely less than 100°.

The pallets are very different from those of any previously described species of *Zopoteredo* in that they are more nearly truly double-cupped, being in this respect more like *Teredothyra*. In *Teredo somersi* the characteristic median sinus can be seen only in the pallets of the very young, never persisting in the mature specimens. In *Teredo clappi* it is frequently obscured or lost entirely in mature individuals, although always present in immature specimens. In *Teredo johnsoni* the sinus is constant in specimens of all ages.

Specimens of this species have been found in the test-blocks placed by the Committee on Marine Piling Investigations at the following locations: Guantanamo, Cuba; Port au Prince, Haiti; Fajardo and San Juan, Porto Rico; St. Thomas, Virgin Islands.

This species is comparatively rare and the destruction caused by it very slight. Few specimens exceed 60 mm. in total length.

At Guantanamo, Cuba, a test-block placed in the water on October 1, 1922, contained specimens 20 mm. in length on December 30th. A special block made of shingles, placed in the water in April, 1923, contained several 60 mm. specimens July 7, 1923. At Port au Prince, Haiti, a test-block submerged June 1st and removed August 14th, contained *Teredo johnsoni* with 30 mm. tubes. At San Juan, Porto Rico, a test-block placed October 1, 1922, contained 30 mm. *Teredo johnsoni* on January 2, 1923, and wood placed in the water July 1, 1923, contained small specimens on August 1, 1923. At Fajardo, Porto Rico, wood submerged from January 9 till April 30, 1923, contained several specimens of this species. At St. Thomas, Virgin Islands, wood submerged four months and removed January 1, 1923, contained several specimens.

FIG. 8

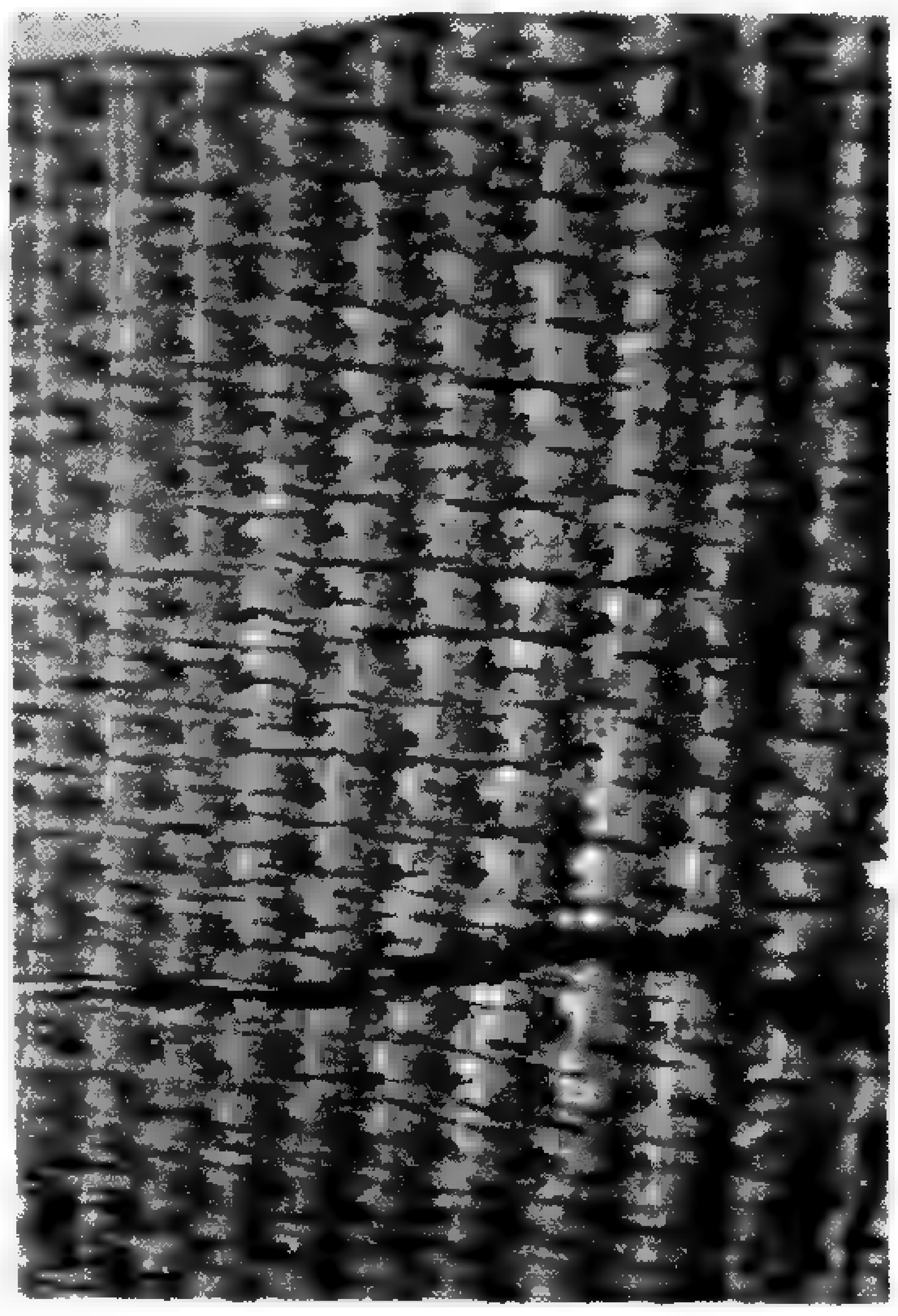

FIG. 9

FIG. 10

FIG. 11

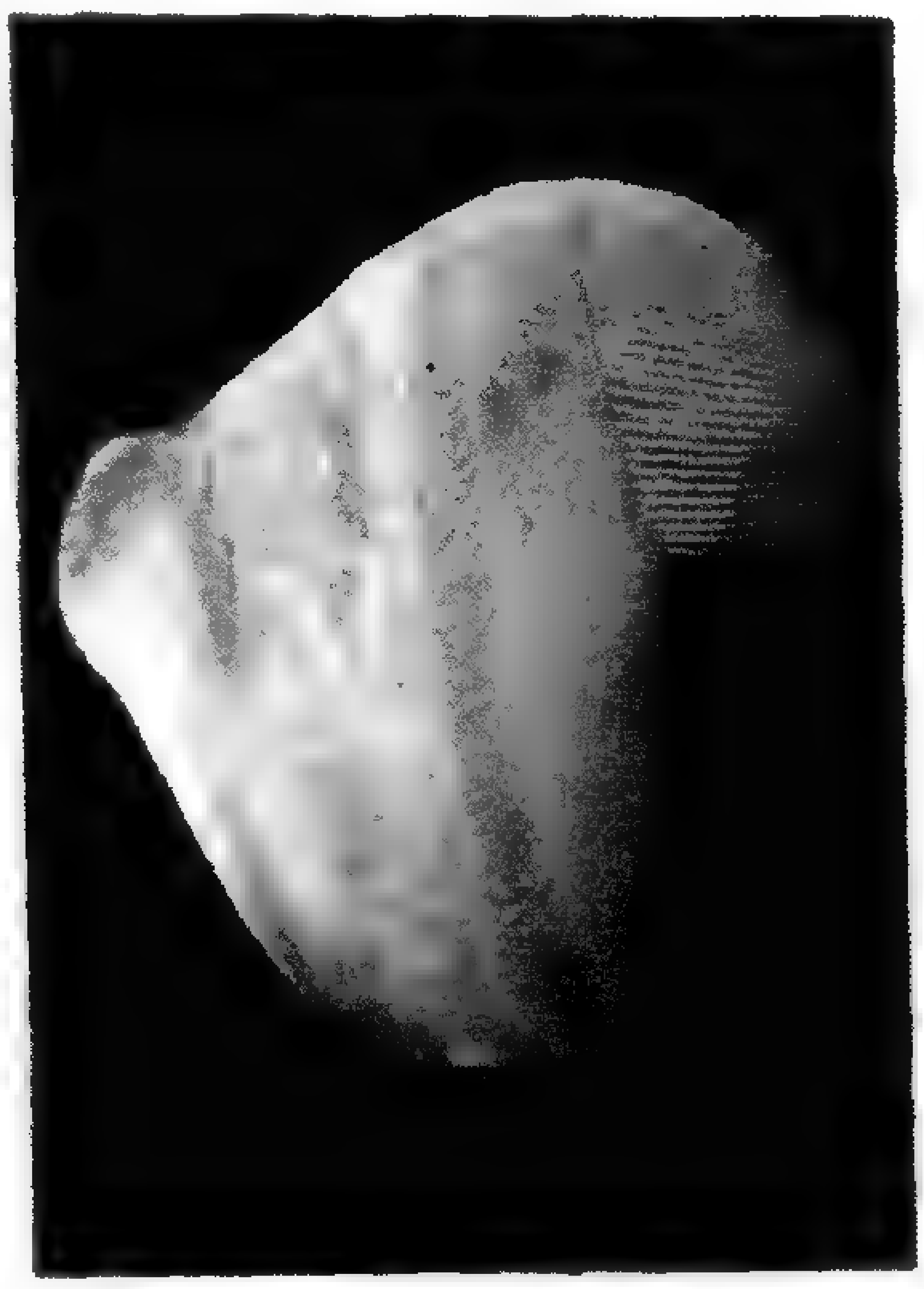

FIG. 12

FIG. 13

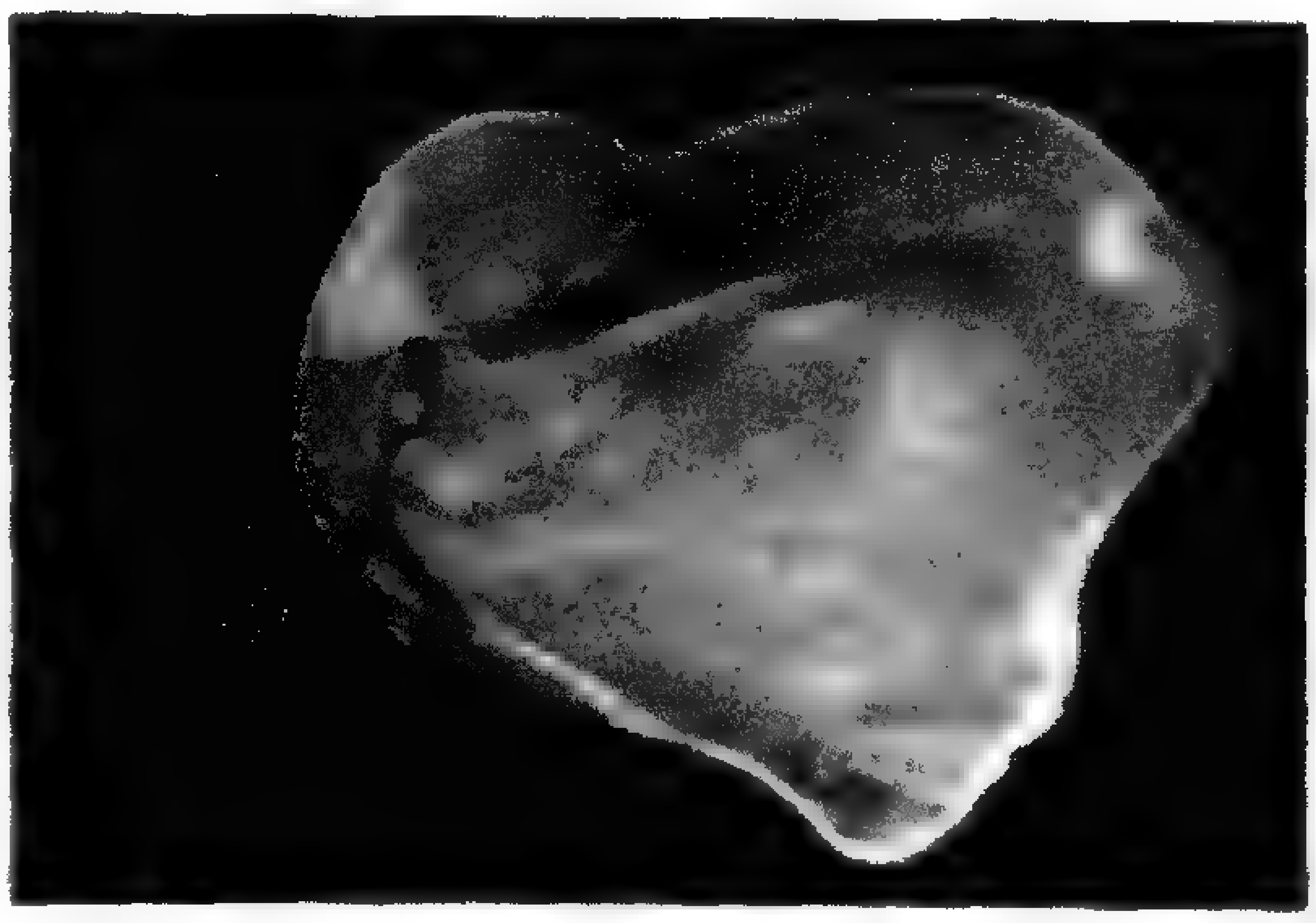

FIG. 14

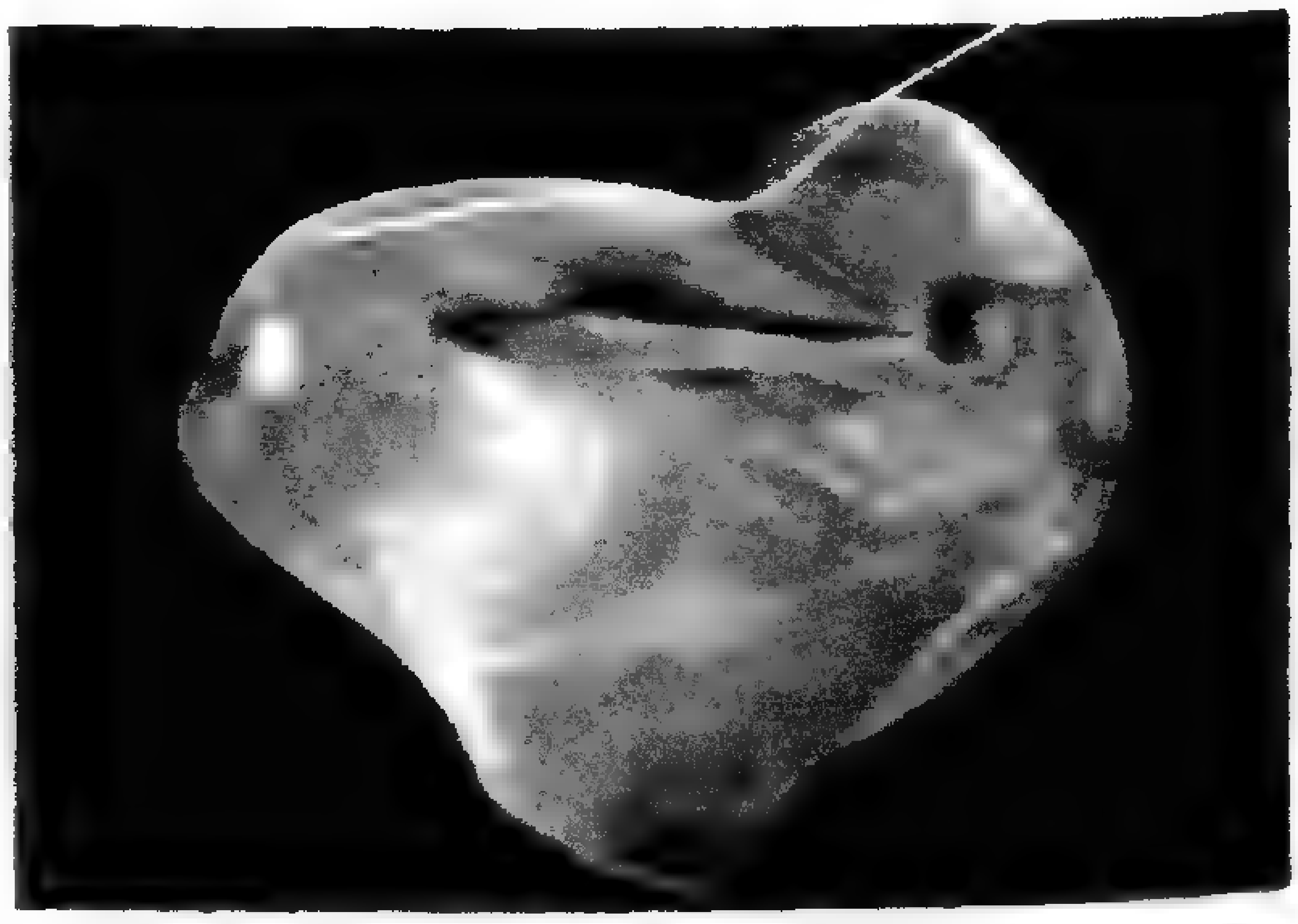

FIG. 15

EXPLANATION OF PLATE

Plate II

(All figures reduced 3/7)

Teredo johnsoni

Fig. 8. Denticulate ridges of the anterior portion. x 130.
Fig. 9. Denticulate ridges of the anterior-median portion. x 130.
Fig. 10. Pallets. x 13.
Fig. 11. Posterior portion of the tube. x 13.
Fig. 12. Exterior of right valve. x 13.
Fig. 13. Exterior of left valve. x 13.
Fig. 14. Interior of left valve. x 13.
Fig. 15. Interior of right valve. x 13.

TEREDO (ZOPOTEREDO) FULLERI* SP. NOV.

Plate III, figs. 16-22.

Shell subglobular, small, bluish white, covered with a strong, transparent periostracum. A thin, broadly curved, incised line separating the anterior from the anterior-median area. The angle formed by the ventral ridges of the anterior area with the anterior rows of the anterior-median area, considerably more than 100°.

Externally, the anterior area, large. In height, slightly less than half that of the entire shell. The denticulate ridges of this area twice as wide as the spaces between them. There are in the vicinity of the ventral edge about twenty-five of these ridges to the millimeter, each ridge bearing one hundred and thirty minute denticles to the millimeter (fig. 16). In the type specimen, the anterior-median area at its widest part is one-half of the width of the entire median area and bears thirty-six closely crowded denticulate ridges averaging, in a line continuous with the ventral edge of the anterior area, forty teeth to the millimeter. Each ridge bears closely crowded, nearly square, denticles, there being forty-five of these denticles to the millimeter (fig. 17). The middle-median area is narrow, translucent, with the ventral ends of the ridges of the anterior-median area disappearing quickly or persisting only as faint growth lines. The posterior-median area opaque, milk-white, smooth, except for microscopic incised growth lines. The auricle small, not clearly separated from the posterior-median area, the dorsal edge concave.

Internally, a large, sharp, curved hinge-plate in the left valve. The blade two-thirds of the length of the

*I have named this species for Mr. Nelson M. Fuller, of the Massachusetts Institute of Technology, in recognition of the assistance he has given me in the study of the shipworm problem.

entire shell, thin, narrow, the ventral end broadly reflected posteriorly. The ventral knob small, somewhat narrower than the supporting middle-median area. The anterior-median area bearing a thickened chord in the vicinity of the anterior area. The auricle extending over the posterior-median area in a heavy callous, ending in an abrupt deep ridge, but with no trace of a shelf.

The pallet (fig. 18) with a very slender, delicate, translucent stalk. The stalk can be seen to extend dorsally a considerable distance through the long, nearly opaque enveloping sheath of the blade. The blade long, narrow, with the sides nearly straight, opaque, milk-white, covered with a very thin horn colored periostracum, which is very difficult to see excepting at the extreme distal end. The outer face convex, the inner flat. The distal end slightly cupped, with the outer face of the blade divided for half its entire length by a narrow, deep, sinus.

The type (Mus. Comp. Zoöl., 45307) is from Christiansted, St. Croix, Virgin Islands.

The measurements of the type are:

Shell, height 3.5 mm.; length 3.5 mm.

Pallets, total length 4 mm., equally divided between blade and stalk; width of blade, 0.9 mm.

The shell of *Teredo fulleri* is very similar to that of other species of the subgenus *Zopoteredo*. It is perhaps most like that of *Teredo johnsoni*, from which it may be distinguished by the more obtuse angle formed by the anterior and anterior-median areas, the shell being in this respect more nearly like that of *Teredo clappi*. The ridges of the anterior area are proportionately larger and the intervening spaces smaller. The internal ridge at the juncture of the anterior with the anterior-median area is constantly much more clearly marked in *T. fulleri* than in *T. johnsoni* or *T. clappi.* The shell is smaller, no specimens having been found exceeding 3.5 mm. in length or height.

The pallets differ greatly from those of any previously described species, so much so, that, were it not for the lack of any trace of a true internal shelf, I should not feel certain that the species belong in the subgenus *Zopoteredo.* The most striking character of the pallet is the milk-white color of the blade through almost its entire length. This is in marked contrast to the other species of *Zopoteredo,* in all of which a large portion of the blade of the pallet is covered with a dark colored periostracum. The long, narrow sinus being only on the external face of the blade, the distal end is not double-cupped as in *Teredo johnsoni.*

This species is probably extremely rare, for it has been found in the numerous test-boards placed by the Committee on Marine Piling Investigations throughout the West Indies, only at Port au Prince, Haiti, and Christiansted, St. Croix, Virgin Islands. At the first named locality no specimen of this species occurred in test-blocks which were submerged from December 1, 1922, until June 1, 1923. These blocks were, however, well filled with several other species of shipworms. In a series of test-blocks submerged June 1, 1923, one of which was removed and examined each month until October 1st, all contained numerous specimens of several species of shipworms, but only the block which had been submerged two months, having been removed August 1st, contained specimens of *T. fulleri.* Of seventy-five shipworms found in this block, only five belonged to this species, the largest with a tube 30 mm. long.

At Christiansted, test-blocks submerged September 15, 1922, and removed bi-monthly contained many shipworms belonging to several species. No *T. fulleri* were found in these blocks until September 1, 1923. The blocks removed from the water on that date contained one 20 mm. specimen. The block removed on September 15, 1923, contained twenty specimens of *T. fulleri*, the largest with a tube 40 mm. in length.

EXPLANATION OF PLATE

Plate III

(All figures reduced 3/7)

Teredo fulleri

Fig. 16. Denticulate ridges of the anterior portion. x 125.
Fig. 17. Denticulate ridges of the anterior-median portion. x 125.
Fig. 18. Pallets. x 12.
Fig. 19. Exterior of right valve. x 17.
Fig. 20. Exterior of left valve. x 17.
Fig. 21. Interior of left valve. x 17.
Fig. 22. Interior of right valve. x 17.

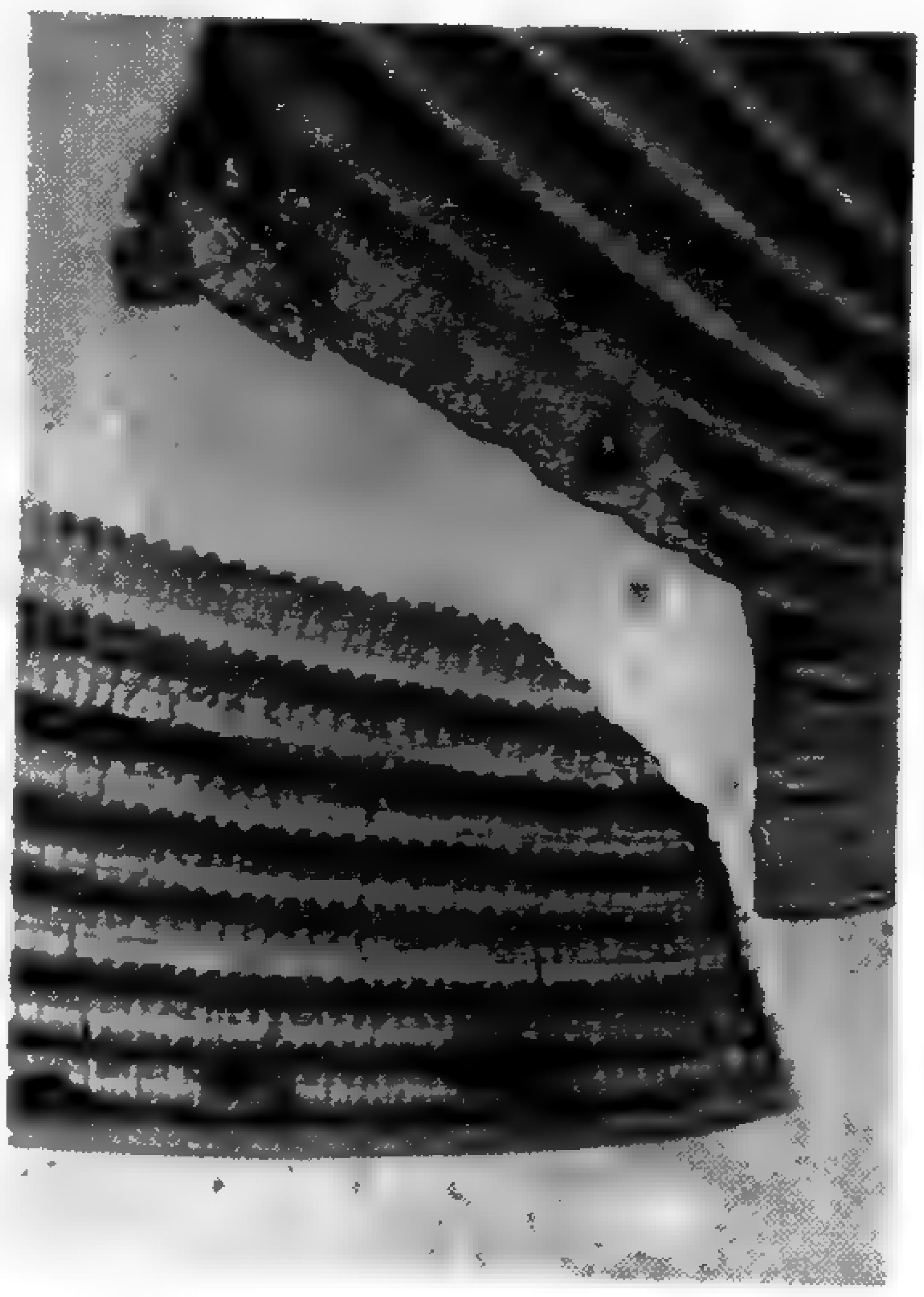

FIG. 16

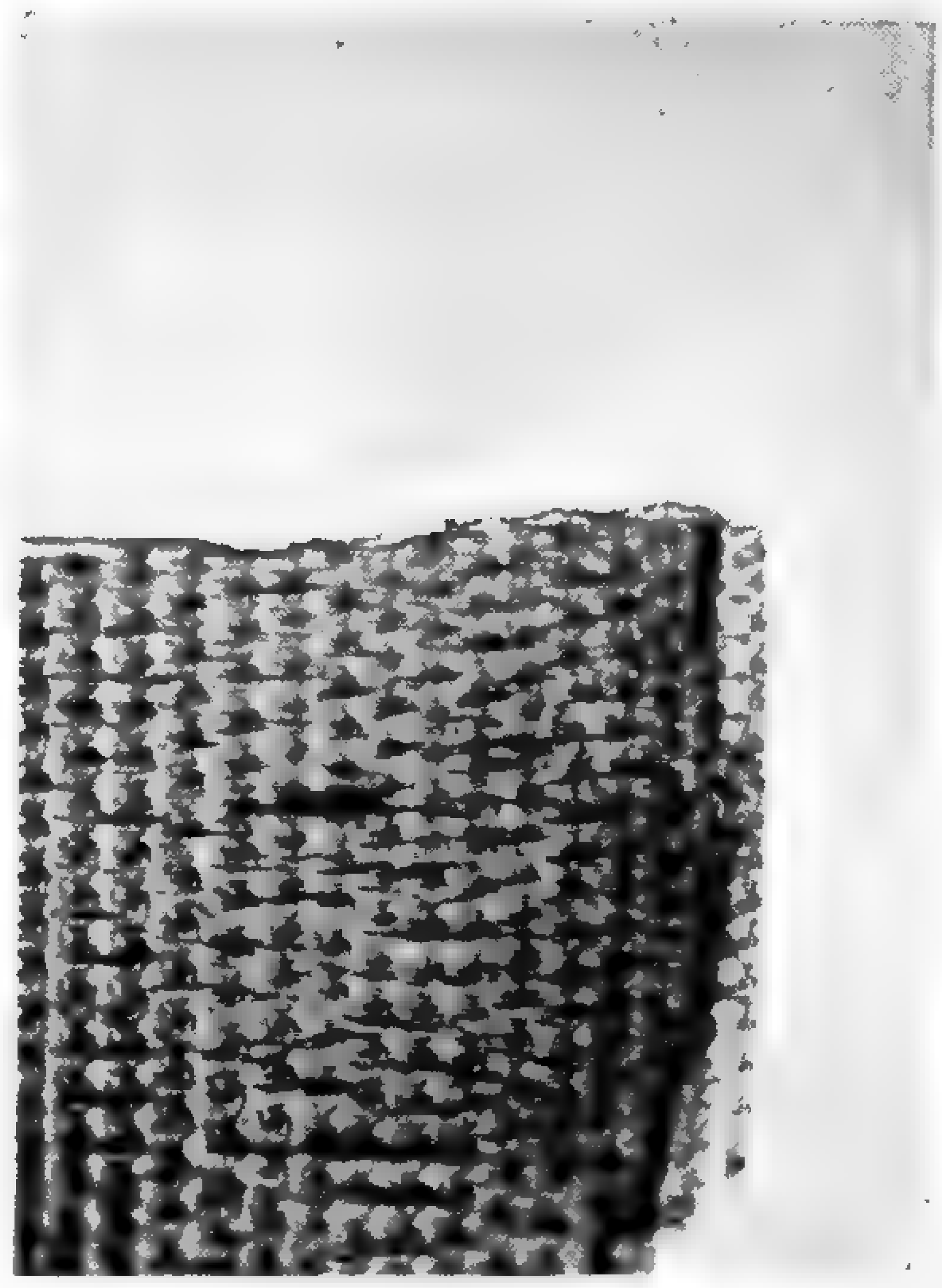

FIG. 17

FIG. 18

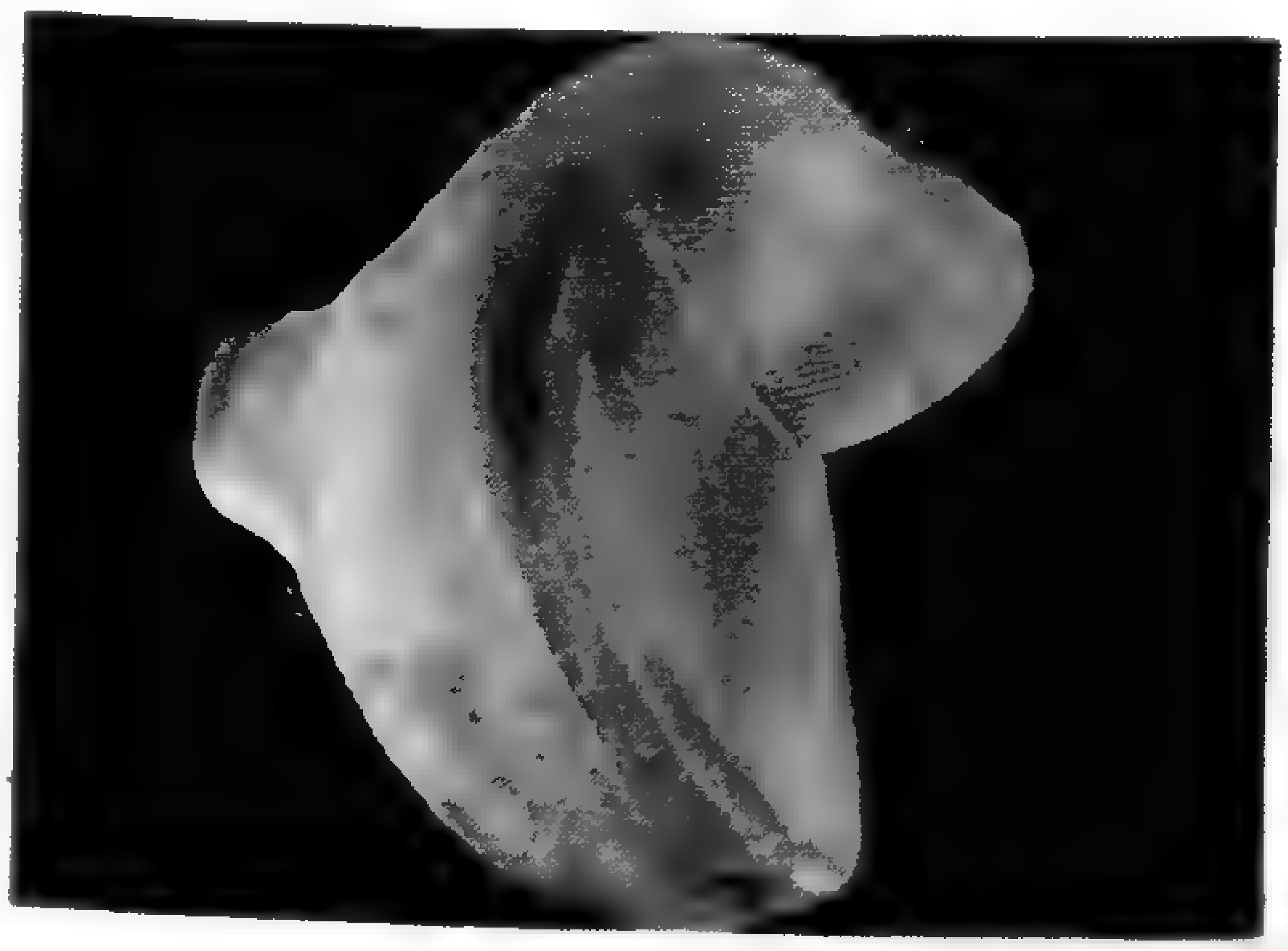

FIG. 19

FIG. 20

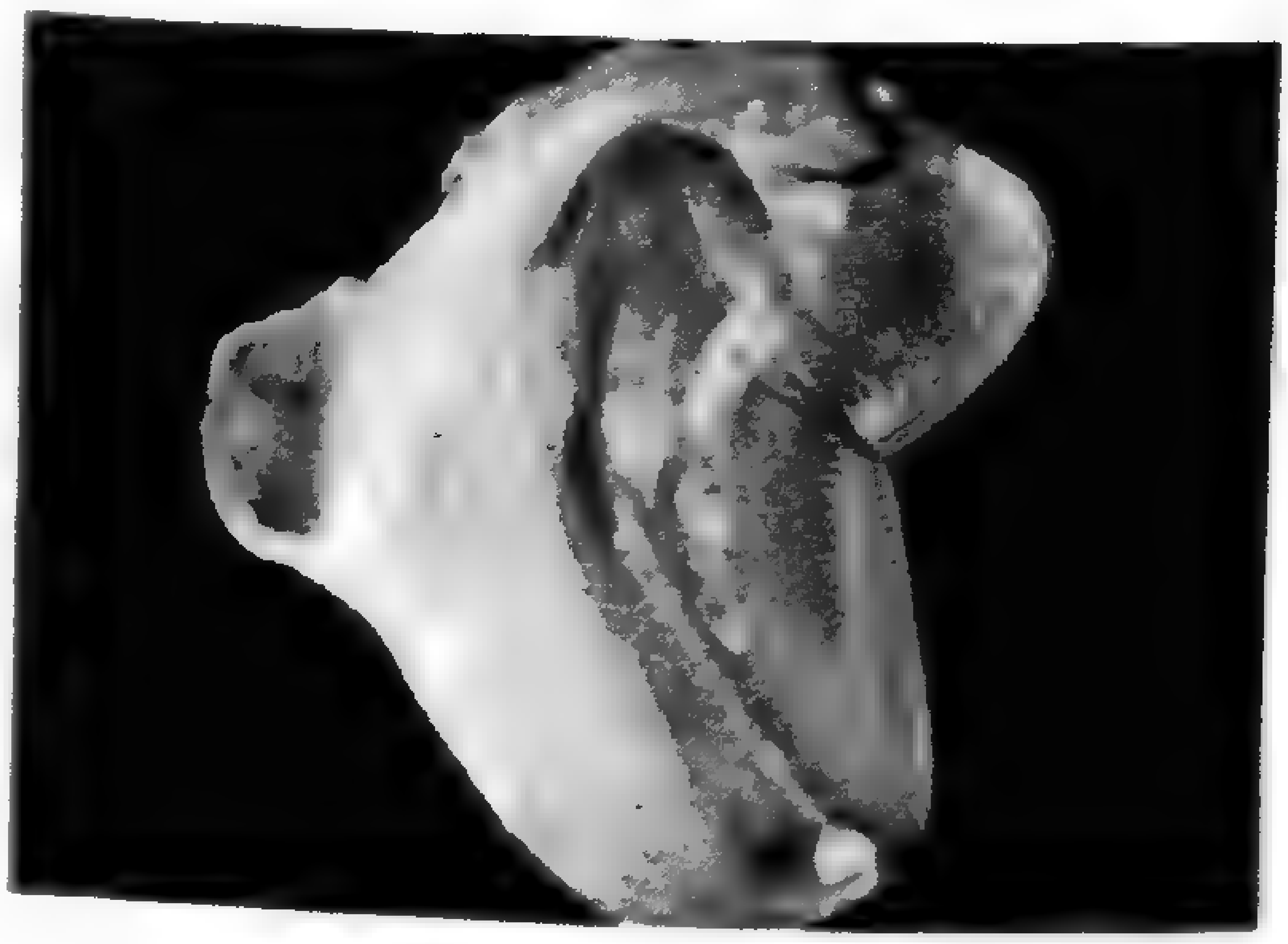

FIG. 21

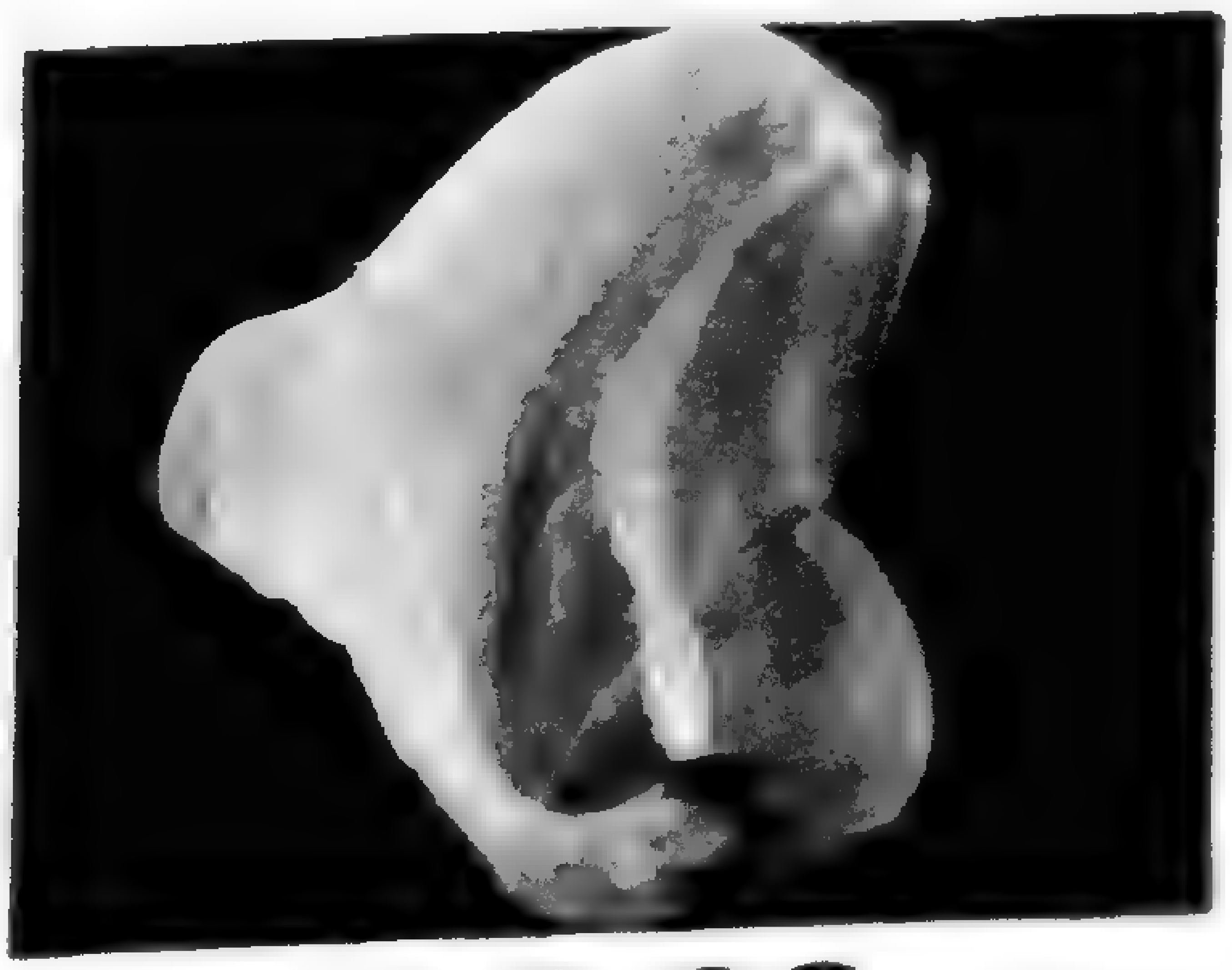

FIG. 22

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Volume XXV, No. 2

MEDICAL FADS AND FANCIES

R. WALTER MILLS

Issued April, 1924

R. WALTER MILLS

R. WALTER MILLS

R. Walter Mills, physician, scientist, naturalist, was born October 29, 1877, and died February 16, 1924. He received the degree of Bachelor of Science from the University of Illinois in 1899, and the degree of Doctor of Medicine from St. Louis University in 1902.

Dr. Mills was a member of the following organizations: American Gastro-enterological Association (President 1923-24), St. Louis Society of Internal Medicine (President 1923), American Medical Association, St. Louis Medical Society, St. Louis Naturalists Club, St. Louis Anthropological Society, American Ornithologists Union, Radiological Society, American Roentgen Ray Society, Academy of Science of St. Louis, American College of Physicians (Posthumous Fellow).

*MEDICAL FADS AND FANCIES.

R. WALTER MILLS.

It has ever seemed appropriate that the Naturalists Club should be addressed on a natural history subject, and I have a feeling that things medical possibly may not lend themselves felicitously to such an end, though I must say that this feeling does not justify itself when submitted to deliberate analysis.

Medicine has been tritely described as an art founded on many sciences—a definition of obvious aptness. One might truthfully elaborate the definition to even more strikingly display the relation of medicine to the natural sciences by stating that medicine is the only art entirely founded on the natural sciences. Anatomy, physiology, bacteriology, chemistry and botany are the purest of the natural sciences. Even of the essentially medical branches such as pathology, hygienics and therapeutics it may be contended that they are subjects founded on scientific observation of natural phenomena. This perhaps by way of extenuation for yielding to the temptation to test the reaction of a body of those interested in natural science to certain views of present medical problems and tendencies. Then again, too, one feels a greater degree of surety in presenting a subject with which he is familiar, and naturally enough anticipates that he may so serve best.

It is to be feared that most of us have at times been moved with a desire to propound to others something of our own convictions and philosophy. It would be an

*This paper was read before the Naturalists Club of St. Louis in January, 1924.

unhappy and surely an unjust view to judge this missionary impulse as altogether a reflection of comfort in the soundness of our reasoning and observation, though possibly not thus untempered. Doubtless it more largely finds origin in the appeal of truth as we see it, though it must be admitted that a certain far-flung charity that would clothe the suffering uncertainty of our less discerning fellows with a satisfying raiment of conviction, may be a factor. It may be also that this uplift impulse is in part stimulated by a certain underlying impression that others, seemingly of considerable intelligence, have quite as definite views and faiths, not running parallel to our own; in fact presenting such wide divergence as to render any common ground of compromise or even any measure of understanding difficult. We reach conclusions that to us seem justified from premises based on apparent facts and experiences at our disposal, and which incidentally, more or less unconsciously, though inevitably, reflect our manner of training and environment.

We see about us scores of beliefs, schools, isms, cults and doctrines of a thousand sorts, covering every conceivable phase of human activity; uplift movements, social service, creeds and faiths, a hundred political followings; reforms in dress, in commercial life, in social precedent and civic movements; the enfranchisement of women; the enforcement of traffic laws and prohibition; ever unrest, readjustment and evolution. Each movement is furthered by sponsors and assailed by antagonists apparently of about equal weight and effect, depending on one's point of view. Both cannot be right; neither is wrong. What adequate explanation is possible; indeed who may accomplish the explanation, though we may perhaps without presumption take stock of certain elements that seem factors in the situation?

The activities of mankind, relatively within an exceedingly short space of time, have been elaborated to a vastness that knows no approximation or precedent. It is trite to speak of an age of specialization, but it is such an age, and a time when each limited activity requires a mental equipment and effort for its accomplishment that fully occupies and exhausts the capacity of its disciple. In all specialization there is a tendency to an unfortunate narrowing that precludes a broad survey of the whole; not only this but exhausts capacity for much. Through endeavor in a multiplicity of directions, we have developed divergently until we have far exceeded our powers of generalization.

The modern practice of medicine presents no exception as to the divergence of views on other subjects; a fact quite apparent to the doctor and frequently suddenly embarrassingly displayed to the patient. It is a hard situation when the seeker for satisfying medical advice is given diametrically opposed opinions by different practitioners as to the causation of his symptoms; when he is told that his chronic rheumatism is due to infected tonsils by the nose and throat man, to intestinal stasis by the internist, an infected gall bladder and appendix by the surgeon, while at the same time his dentist naively suggests the functioning teeth as the undoubted primary cause of the same infirmity. Regrettably few of us have any capacity for seeing ourselves as others see us. The patient admits without effort the ridiculousness of such a situation in which prosecutor, judge, jury and executioner are embodied in one with a fee contingent on conviction. He may even infer unpleasant motives for such disharmony, but he cannot see a similar situation in a score of issues in which he has his own personal convictions. May I gently suggest the League of Nations, Prohibition, and German Reparations.

If the public finds difficulty in adjustment as to views on subjects of general interest, and if certain positions of physicians seem unappealing, its own efforts at the solution of medical problems lead to ends that to the medical mind seem little short of devastating; self-diagnosis having as its apparent object the selection of that non-disfiguring disability which is least disagreeable to contemplate, that never ends fatally, and can be readily cured with a laxative pill. Systems of exercise, vibration, Christian Science, and New Thought, osteopathy and chiropractic, baths, ranging from vapor to mud, cancer cures, the stock of the family medicine closet, everything from walking barefoot through the grass and the laying on of hands to Lydia Pinkham's Compound, all are tried. And the astounding thing is that the patient as a rule gets well and lauds to heaven that remedy or system that he happened to be taking or employing at the time of his recovery. Apparently he would be as well off if he had the name of each remedy written on a slip of paper and placed in a hat to make selection by the grab-box method—the result seems about the same. What can the answer be? It would seem that there must be forces, operations and reactions in the human body that are far beyond our knowledge; that we are arguing and attaining conclusions not based on adequate premises, either as to the cause or the interpretation of results. It would seem that we should look to scientific medical people for saner interpretation and direction. In considerable measure this is afforded, in spite of surface incongruities, but if medicine now is in possession of certain seeming fundamentals, every medical advance, every research, opens up many unappreciated and unforeseen problems—sidechains, ramifying in a score of confusing and interlocking directions. We know so little when we had thought to know so much; we are no longer so sure.

Most of us have lived within the most momentous decade that medicine may ever know. Not the period of Pasteur's activities or the application of the principles that he propounded; not the period of the development of surgery or the pathological teachings of Virchow and Koch, but in the time that saw a lessening of the dominating identity of the general practitioner and the invasion of his field by the various specialists, with resulting vastly more accurate knowledge. We remember the family doctor of our childhood—revered of memory. He of the flowing beard, frock coat, bag of accoutrements, and with all the gentle yet persistent aroma of iodine. Without jest, he was the friend of the individual, the confidant and advisor of the family. The like of his beautiful relationship to us will not soon be seen again. His was the dignity that encompassed the gamut of human emotions. On the other hand, while his moral function was great, and he did a vast good in the alleviation of suffering and the treatment of simple diseases largely by empiric measures, it is but fair to say that his information was not great—not so much through deficience of his own, but as the result of the lack of real knowledge of the medicine of a generation ago. The system of his polypharmacy, his wholesale prescription of nasty medicines, did not differ from other species of charlatanisms save through his belief and sincerity. While we do full honor to his altruism and the nobleness of his personal character, and realize that his shortcomings were those of his time, it does seem that the modern doctor in his love of truth loses nothing by comparison. The old doctor promised the control of all diseases, if not in words, at least by action and reference. Yet there must have been times when he doubted; if not, his ignorance was his cloak. He never knew the soul-searching devotion to truth that does the modern scientific medical man, whose standing is largely set among his fellows by this asset. He did not spend half a life time in preparation for his work, but instead a meager two years. The old doctor never admitted his wrongs or errors. There was no wholesale devotion to large charities at considerable financial loss, no lavish giving of valuable time to research and teaching that is taken as a matter of course by the modern doctor. There was no preventive medicine. Modern medicine is the only profession that ever cheerfully undertook to undermine itself for the good of humanity. There was no group medicine, no willing reference of patients to others more capable of caring for them in their particular illnesses. The relationship of the old doctor to his professional fellows was not particularly pleasant, in fact usually unpleasant. They kept it well within the family, but the medical feuds of yesteryear are not a pleasant contemplation. Fortunately they are no more. The modern association of physicians of like fields in groups and clubs for the helpful discussion of matters pertaining to their subjects, is one of the pleasantest features of the present day profession.

But if the partial dismemberment of the profession into numerous specialties has effected a vast good in directions suggested, it has led to the same difficulty that has been experienced in all other forms of activity pursued intensively along limited lines. The tendency is for each to see the whole through his particular avenue of approach. It is a problem as yet unsolved—a product of an intensively productive epoch. Also it is a detriment that in this its formative period, scientific medicine is still cluttered with reflections of the unfortunate traditions and practices of earlier time. Again all are not as we are, there are many publicans and sinners in the guise of specialists who trouble greatly and to whom specialization affords an easy field for exploitation. Possibly, and it is to be hoped, the future will see great simplification, as principles and practices become standardized, so that it may be possible to develop general practitioners of a super-sort, men of the broadest and noblest type having effective knowledge of the array of supporting specialties and sub-specialties, chief of whose functions will be the temporary reference of his patients to such sources for special help. He will indeed be the greatest specialist of them all, a reincarnation of the old doctor, with all his priestly functions and with a capacity for truth that his predecessor never had—certainly the course seems in this direction.

A great, possibly the greatest, problem with which present-day practical medicine is concerned is that of the overpowering elaboration of diagnostics. Our old doctor of the past generation had few diagnostic tools aside from those of nature's endowment; his eyes, ears, fingers, his powers of observation and reason; though truth to say if a comparison must be drawn, he had in these diagnostic weapons that have never been surpassed. They are still paramount though no longer the only tools available and their effectiveness is being approximated by scores of diagnostic means that have rendered diagnosis enormously more accurate, also enormously more difficult, of effect. One might call to mind the developments in modern medical laboratory work accruing chiefly through the application of organic chemistry, microscopy and bacteriology—the various functional tests and determinations, the extraordinary advance in haematology leading to the practical utility of blood cultures, transfusion, tests for occult blood in excreta and diagnostic cytology. Recall, too, the developments of thermometry, endoscopy and electro-cardiography and, greatest of all, the X-ray.

It is curious that it is only in retrospect that we are able to evaluate great advances. The inception of the great change is so insignificant and its development so gradual that we cannot realize its present or final import even when the action has acquired great momentum. It is scarce more than twenty years since Roentgen made his epochal discovery. In the early years of its medical application its field of utility was considered limited to the detection of heavy foreign bodies and the study of fractures. Gradually other outlets were found for its use until today it has riven diagnostic traditions in every branch of clinical medicine. If its growth is but a percentage as remarkable in the future as it has been in the past, and personally I cannot believe that it will be greater, it will soon come to occupy a position of domination—the first of laboratory methods to supersede the supremacy of clinical observation. The only thing that has prevented this occurring up to the present is the technical difficulty connected with its use and the as yet unsolved problem of educating physicians and students in X-ray interpretation—one of the most difficult arts with which medicine has yet had to deal.

The mention of certain advances in methods of diagnosis was made in order to present a problem that is seriously concerning all medical minds; a problem without precedent and with no very promising solution in view; the question of how it may be possible to make available this vast advance in diagnostic refinement to the public to the satisfaction and encouragement of physicians.

It is perfectly obvious that no one man may have an even working knowledge of the various diagnostic methods now developed. It has come to pass that of even the specialties no one person can exhaust the possibilities. Each is now split into sub-specialties through the unusual accomplishments of different workers developing different lines within the specialty. Since this is true, it would seem to lead to the solution that the only way by which this vast store of valuable knowledge can be made available to the patient is through some sort of coöperative arrangement. The idea has been and is being tried in various forms; it cannot be said so far with any great success. Perhaps the most promising arrangement is to be found in what are known as the one-man groups, a few of which are in operation. In them one dominant personality, highly accomplished in certain lines of work, is supported by various experts in other branches. The Mayo Clinic and the Cleveland Clinic, of which Dr. George W. Crile is head, are leading examples. These one-man groups have the weakness of lack of permanency, the anticipation being that they will disrupt with the loss of the chief. Coöperative groups, closed hospital groups, and groups having a purely diagnostic function attempting through this to serve the practitioner, are other variations. The difficulties in the operation of any such schemes are those of personal adjustment between the workers in the group —since most men enter medicine for one reason, because of the independence conferred. The financial problems concerned in group medicine are legion, as the activity implies a great increase in labor on the part of the workers and the pro-rating of a single fee among them. The problem of the relative values and compensations of the different members of the group, of necessity to be adjusted among themselves, creates a situation not making for amity. Closed hospital groups imply a heavy endowment together with the resulting obligation to accomplish a large amount of teaching and charity work as they are generally connected with medical schools. While they have their function as practical outlets for medical practice, they cannot be considered highly successful, as to even a greater degree than in the instance of other group plans, the personal relationship between physician and patient, one of the sorest deficiencies of any group system, is most difficult of maintenance. Again, hospital groups are in the main founded by men of great wealth who evolve systems of hospital practices tinctured with the commercial standards that gained them wealth, and naturally these do not take into consideration the happiness of the practicing physician who finds himself placed on something of the superior plumber basis.

There are tendencies toward state medicine, though viewed with concern by most thinking medical men as affording opportunity for graft, politics, and retrogression, through the lowering of incentive to personal accomplishment and as tending to develop a commercial medicine *en-bloc.*

The present most happily functioning arrangement, though something by way of a makeshift and the result of spontaneous evolution, is the practicing of certain branches of medicine by certain men to whom patients refer themselves on their own idea of the nature of their ailments or in a smaller percentage of cases, to whom they are sent by practitioners or fellow specialists. Disadvantages of this system are that examinations are inadequate in lines other than that in which each specialist is expert; that there is a tendency for a widening of the field by each intensive worker to include conditions with which he is not adequately familiar; the over-accentuation of conditions falling within the specialist's field and the cost to the patient. The great advantages are that the patient has the benefit of a skill and judgment that cannot as a rule be commanded in a group and he also derives a personal attention, moral support and the security of a responsibility on the part of his physician not available in any group. The arrangement is highly satisfactory to the physician, affording him independence and stimulation to put forth his best efforts through which he may anticipate increased professional reputation and financial reward. Certainly this method of practice has to date proven the most generally satisfactory, though far from ideal, as exemplified by the ophthalmologist, the surgeon, the nose and throat specialist, and so on. In the future it seems not improbable that in addition to the elevation of the family physician, and working in conjunction with him, we shall have very small groups of the one-man type limiting themselves, though less restrictedly, to certain lines of work, and spending a much larger proportion of their income in laboratory work, technical and non-medical support; anticipating adequate return through the ability so developed to do a much larger amount of work at a lower cost to the patient.

The entire medical fabric is in a flux of reconstruction—there is so much one feels like discussing. I had in preparation reviewed a number of subjects whose presentation it seemed might appeal to your interest. The list was discouraging, if one were to do each any sort of justice. I hasten to assure you that less will be attempted.

Rather let me try to speak carefully of a few things that in my own line of work exemplify present medical thought and seem less appreciated by people generally; also certain generalities resulting from my own personal investigations. It is not easy to do and at the same time be intelligible, for between the physician and the public, the doctor and his patient, even the doctor and other scientific men, there is a great gulf fixed—the difference in training, manner of thinking and precedent generally, that results in different positions and conclusions. We see only as we have been accustomed to see, and reason only as we have been accustomed to reason—we are all specialists in our own lines.

Perhaps it might be considered that fatigue is the greatest single factor in biological degeneration—the constant pounding that we receive nervously through unhappy emotions, anxiety, fear, and hope deferred. The physical injury through the mere process of living and under which joints stiffen, arteries harden and muscles lose their elasticity as we get older—the thousand natural shocks, are the greatest factors making for physical decadence. These things we know, but we do not pause to consider or crystallize in our minds, until in some way the facts are shunted to our attention. Rather we think of the injury done by alcohol or cigarettes. On the other hand, one might contend that a life of sustained high tension and constant nervous irritation did more harm than some alcohol, and that high heels did more damage, through making for fatigue and strained spines, than did cigarettes, yet a very good case might be made out along these lines nevertheless—simply a difference in point of view.

Reference was made a moment ago to evidence that suggested that our deductions drawn from superficial examples as to the curative efficacy of certain measures were probably often incorrect. There seem certain reasons for this that are less easy for people generally to understand. There are certain physical reactions that make it possible for all sorts of isms, cults and irregular specialized methods of healing to flourish, apparently through successful results. We patter about the influence of mind over matter, and there is no doubt that there is such a great principle. But there is another less obvious factor making for the success of apparently irrational methods of treatment. This principle might be defined as the elevation of our coefficience of resistance. It is true that few if any of us are entirely well. We all have our infirmities, visible and invisible. Now our feeling of well-being, or the lack of it, represents a balance between the unfavorable influence of our infirmities, and the favorable influence of our natural resistance—just in the same way that one might strike a balance in auditing the books of a commercial concern. When we are very ill our physiological resistance capital is exhausted. When we feel very well our physiological balance is in a prosperous condition. Now if in attaining our physiological balance there occurred either a factor making strongly for betterment, a heavy credit, or a single factor making strongly for disaster, a considerable debit, the acquisition of the one or the other would throw the final balance either on the favorable or unfavorable side. Since it seems hardly possible to put this clearly in a few words, may I resort to illustration: Suppose one is apparently in good health, otherwise, but suffers from a chronic recurrent ulcer of the stomach. This disease characteristically tends to go into definite periods of aggravation and betterment. If this person met with much nervous strain, business reverses and the like, his ulcer would become active, because his general resistance, his tendency to the natural cure of his ulcer would then be lowered, and he would suffer with one of his stomach attacks, due, he would be assured, to obvious nervous causes. If his troubles, business, domestic, or what not, suddenly ended, or if he had a refreshing vacation, his indigestion would cease, because he thus raised his general resistance to the point where his ulcer again became temporarily healed. He returns from his vacation having gained in weight and general well-being to insinuate to his medical advisor that his diagnosis of ulcer was incorrect, as he no longer finds it necessary to adhere to his diet but can eat everything and all he wants of it. Christian Science, New Thought, or any similar means would do the same thing.

Let me attempt another illustration. A patient suffers from a bad static back, primarily the result of a spinal curvature. He also, let us assume, has some concomitant digestive disturbance, say in reality due to an unsuspected gall-bladder infection. Now all digestive processes are entirely controlled by nerve impulses. If his back from any of multitudinous causes becomes temporarily worse, his indigestion will be worse, because his nerves as the result of his backache are then in a highly irritable state. Now suppose he went to an osteopath for treatment of his back. These people undoubtedly sometimes do good in such conditions, not according to their silly claims of replacing vertebrae, releasing nerve pressure, and the like, but through loosening up the muscles, improving their blood supply and relaxing them by massage. Our patient's physiological balance may thus be so favorably influenced that his indigestion becomes greatly better, because getting relief from the load of suffering and irritation due to his backache suddenly so relieves his general nervous irritation that his digestive organs function without protest, even though really below par.

The matter of the modern theory of focal infection was mentioned as an illustration of a subject in which the public often concludes a not flattering view of the medical profession. A situation sometimes develops in which the patient is advised from various medical sources to have tonsils removed, sinuses drained, gall-bladder excised, and large numbers of good-looking teeth drawn for the cure of some apparently entirely foreign condition, as a chronic arthritis—rheumatism if you will—in I am afraid to venture what proportion of cases without beneficial results. Yet there are few deductions founded on better evidence or more logical reasoning than this same theory, whose practical application at times effects most spectacular cures. The theory implies that certain conditions such as chronic arthritis, most heart diseases, neuritis, appendicitis, gall-bladder disease, colitis, stomach and duodenal ulcer, and so on, originate from organisms gaining a foothold first in some other portion of the body, and later being carried to these secondarily affected parts by the blood or lymphatics. But if many diseases originate in this way the number of places in the body where organisms may find lodgment and establish themselves as possible primary foci is even greater. A person may suffer from chronic arthritis that we have every reason to believe originated from a distant primary spot of infection, just as weed seeds are blown from our neighbor's garden to our own. The great problem is to find out from what garden these seeds come, and eradicate them there. We may strike it in the first place by the removal of an infected tooth or tonsil, but the chances are we will not. Theoretically we should continue the search until the original focus is found; a prospect entailing great diagnostic energy and skill and often severe abdominal operations. Only too often the patient gives out before the doctor. A casual mention of some of the diseases known to be due to focal infection may indicate how hard the problem is. Valvular disease of the heart, endocarditis, hardening of the arteries, pericarditis, osteomyelitis, periostitis, neuritis, herpes, appendicitis, inflammation of the gall-bladder, stomach and duodenal ulcer, and the greatest incapacitator of them all, chronic arthritis.

The list of sources from which an infection may arise primarily and from which other secondary serious diseases may originate is even larger. I might mention pyorrhœa, abscesses about the teeth and gums, tonsilitis, inflammation of the nasal sinuses, all sorts of bronchial conditions, pleurisy, multiple small ruptures of the colon, pyelitis, inflammation of the kidneys, also of the tubes and ovaries, and special glands, hemorrhoids, fistula, even slight inflammations about the finger nails. So the problem is complicated and implies for its successful issue first an accurate diagnosis of the disease —the diagnosis in part to determine whether the disease be one that might originate from a primary infection, a very difficult matter in itself. Secondarily is implied the eradication of all possible sources of primary infection. The wonder is, not that the method does not always succeed, but that it ever does. Now the specialist or dentist, subconsciously accentuating matters in his own field and knowing that each possible focus must be removed anyway, is prone to lay too much stress on the obvious infection with which he is so familiar, as the probable cause of the secondary disease. This often leads to ludicrous situations. Only a week or so ago a dentist specializing in the removal of teeth, urged the extraction of a last, not very obviously infected, molar in an elderly gentleman who was a patient of mine, with the assurance that its removal would cure his rheumatism; the previous extraction of the majority of his other teeth by the same exodentist having failed to do so. The patient had a bad chronic appendicitis and an infected gall-bladder containing stones. A few days later he—the patient, not the dentist—was sent to an insane asylum. His pain, his "rheumatism," was really the premonitory expression of a severe central nervous system disease, having nothing to do with joints, gall-bladder, appendix or teeth.

There is another factor that makes the whole situation difficult and that is that all of us, in a measure, are diseased; not only superficially through infirmities with which we are familiar, but internally and in numerous unappreciated ways. We are all rather familiar with the fact that as we get older, the hair turns grey, that we must wear glasses and the teeth need much repair. We also more or less consciously realize that our capacity for bodily activity greatly diminishes. We cannot dance or run or do other things we did when we were younger. Just as surely there is a similar decadence of numerous internal organs and parts. We see but the evident surface manifestations that are expressions of internal deterioration. In something like 80 per cent of elderly people there is gall-bladder disease as shown by actual local evidence found *post mortem.* There are practically no normal appendices—all are somewhat diseased, just as tonsils are practically all slightly inflamed. We all have some pyorrhoea. We have all had pulmonary tuberculosis—not the slightest doubt about it. We laugh about our grey hair and our glasses, and are shocked when we are told of these quietly progressive internal changes. Now fancy the difficulty of saying which of these is responsible for a chronic arthritis or other systemic disease known to originate from a primary focus of infection.

There are certain subjects that indicate definite trends in modern medicine that are so difficult to put across that I hesitate, though may I attempt it? One of these is what might be termed the subject of individualization. Our old doctor was credited with understanding the individual constitutions of his patients. Whether he understood them or not, he learned something about them. Now of recent time we have come to consider that each one of us is a law unto himself, both anatomically and physiologically; that our individual internal structure, and the operation of our internal functions are just as personally peculiar to us as are our faces, voices, mentalities and dispositions.

A few years ago we heard much of abnormal displacements of the viscera. The stomach had fallen, or the colon, or we had floating kidneys. During the last decade, since the truly wonderful revelations of the X-ray, if we followed such a doctrine, we should be forced to believe that there are few normal people. Let me review as briefly as possible the factors leading to the conclusion that our previous views as to displaced viscera were largely incorrect, and only represented our ignorance. If one were to have arrayed before him the bodies of a vast number of people, he would find no two alike but instead a great dissimilarity in bodily proportions, length of chest and abdomen, width of pelvis and so forth; just as great dissimilarity as in their faces. We do not become educated along these lines on account of clothes. Now if we had an X-ray study of the organs housed in these different bodies, we would find if anything a more striking dissimilarity. The stomach of the one looks little or nothing like the stomach of the other. We should see, that in a general way, certain types of stomachs corresponded to certain types of bodies, just as in a certain type of person we expect certain bodily and mental peculiarities. The heavyweight prize fighter is a different type from the artist or musician. A correspondence of types of viscera to types of bodies is in large measure a natural result. The abdomen of certain capacities in its various regions can only house viscera of a certain form. For instance, a long body may only have a long straight up-and-down stomach—there is no room for a stomach anywhere else or of any other kind. A woman with an unusually wide pelvis will have a low position of the viscera because something must fill the pelvis. So we must be cautious before we speak of a dropped stomach. A low position of the stomach or of the kidneys is perfectly normal in people of a certain type. All physicians do not subscribe to this theory so you must take it as you will. However, the tendency is more and more to drive these doubting ones from their position of espousing a one-type standard with all other persons considered as abnormal deviations from such. To repeat, the old idea led us nowhere, unless to conclude that almost no one was normal.

In the same way physiological manifestations, the action of stomach, intestines and many other things vary greatly, in general corresponding to the type of individual. The stomachs of slender persons are nearly twice as slow in evacuating food as are the stomachs of heavy people, probably as an adaptation of nature—the heavy person needs more food consequently his stomach operates more rapidly. It has been found that defecation is normally much more frequent in heavy people; as a rule, perhaps two or three times a day. In certain slender types there is a question as to whether or not a daily action is necessary—though this with caution. In similar fashion blood pressure is lower in slender people and higher in those of heavier type. Certain digestive juices are weaker in certain slender types and stronger in others, and so on through the whole list of bodily functions. To complicate the situation there is also a relationship of visceral, physical and physiological peculiarities to age. We look at persons and guess their age with fair accuracy—at least to ourselves—but what makes one person look old and another middle-aged? We see only the surface of the body. These surface peculiarities are but reflections of deep interior changes. The shape of the viscera, heart, stomach, intestines, all may indicate the age to a practiced observer as readily as does the face or figure. Who then is normal? Is grey hair abnormal? Not in some. No one has ever successfully defined normal though anyone may ask what is normal—for instance what is normal blood pressure? We must judge each person individually, anatomically and physiologically, just as we judge them in every day life individually, and as we unconsciously do, as influenced by age, bodily type, and the like.

May I suggest another difficult subject. We never did understand, we only thought we understood, something of digestive disturbances—indigestion, if you will. People said that they suffered from gas and biliousness and noted that they got relief when they stopped eating or took purgatives. We learned from experience that many of these indigestions were curiously secondary to disease of certain organs, such as gall-bladder or appendix. At least they were relieved permanently by successful operations on these organs. In other cases they were relieved permanently by an improvement in constipation. We said that these dyspepsias were reflex. We had been in the dark for centuries, we only had the physic of the ancients, until the marvelous revelations of the X-ray which begin to indicate a totally different cause.

Let us visualize the stomach and intestines as a continuous tube through which food passes in orderly fashion; slowly pausing in certain locations as in the stomach and cecum, and passing on more rapidly in others, as in the small intestine. In other words, stomach and intestines move their content on a schedule just as a railroad train operates, slowly and with delays in yards and terminals, and rapidly over long stretches of track between cities. Now if there be delay at any one point in this traffic, the movement behind it will be slowed and congested. Exactly the same thing takes place in our alimentary tract. If the appendix is bad and has resulted in surrounding inflammation with crippling of the cecum from which the appendix arises, the intestinal contents do not pass by this point as rapidly as normal, but delay there and congest behind it. Not only immediately behind it, but the recoil (as we call it) is felt far distant in front, even as far back as the stomach. It is also probable that this is in part due to the local disturbance of the rhythmic alimentary contractural gradient that has been determined as existing and as flowing progressively, ever distally, over the stomach and intestines resulting in the onward propulsion of their contents. This, just as a ripple in water, once broken cannot progress beyond the point of break. So in chronic appendicitis the stomach may be secondarily delayed in emptying with resulting feeling of pressure, or gas, as people call it, because they can relieve this tension discomfort by belching. Now successful surgical treatment of the appendix will, so to speak, clear the track so that traffic may go on again in more nearly orderly and timely fashion.

And now ensues another factor vastly portentous and regarding which our comparison of the traffic on a railroad will not hold. With increasing congestion behind a diseased and delaying point, there results slight dilatation of such congested parts of the intestines in front of it. Not only do their contents move on less rapidly than normally, but the bowel actually undergoes a slight stretching as the result of its constant heavy load. Let me drop this point for a moment and consider another necessary to understand before one can appreciate what finally occurs. There are in our stomachs and intestines a series of four sphincters. One of these, the cardia, is at the point where the esophagus joins the stomach; another, the pylorus, is the gate-way from stomach to intestine, and the fourth, the recto-sigmoid, is between the lower bowel and the rectum. These valves are soft mouth-like structures, of great delicacy in sensibility and action. Now if the bowel is slightly stretched local to them, these sphincters will be stretched in common, so that they no longer close completely, in other words, they remain constantly open and are incompetent, or as one might say, leak. So if we have a congested condition of the traffic in the intestines resulting in their slight stretching, and if the segmenting valves consequently no longer perfectly close but remain open, it follows that there will be pernicious transmission of pressure from one part of the alimentary tract to another, for one function of these same valves seems to be that of keeping the pressure in certain sections of the gut at a certain favorable degree. We feel this abnormal pressure, which can be relieved by belching or otherwise passing gas, but which the X-ray suggests is not due to gas but results from congestion of the intestinal contents and resulting delay in its movement. This doctrine we may call the theory of the abnormal transmission of intravisceral tension; a sort of intestinal blood pressure.

The foregoing conception has allowed us to begin to understand that most common of all diseases, constipation, an appreciation of whose seriousness grows upon us as we begin to understand it. It also results in the same intestinal engorgement, pernicious pressure and broken valves that I have mentioned as produced by other causes. Taking purgatives relieves for the time being, because a purgative sweeps out the whole intestinal contents and thus relieves the tension. But it is a vicious habit and tends more and more to injury if continued. No one was ever cured of constipation by taking purgatives, rather it tends to make the condition constantly worse as stronger and stronger agents are required. When one takes a purgative the entire contents of the intestines are liquefied and greatly increased in volume and so remain for a much longer period than we should be led to expect. There is also a straining, disorganizing and injurious action on the part of the intestines, which if continuously repeated leads to leaking valves and abnormal transmission of pressure.

The taking of enemas is hardly less unfortunate. They cause stretching and irritation. Many persons labor under the mistaken idea that they thus beneficially aid nature with internal ablutions. Nothing could be farther from the facts. The colon has been designed for the accommodation of its peculiar semi-solid contents through countless ages of evolution, and its functions are supervised by exquisite reflexes that act automatically; a far older and more effective control than by the recently acquired and not always happily functioning brain of man. Again enemas are highly irritating. An expert by proper ocular investigation can tell by the irritation of the bowel lining when a water enema was taken the day before. People take these liberties because the poor colon cannot feel—has no sensibility except to pressure. As well put a cinder in the eye to wash it out, or soap suds in the nose. The injuries that result are very real—the broken valves, the numerous small ruptures of the colon that we call diverticula, the back pressure, the nervous irritation, what you know as biliousness, the general miserableness that results. There are ways of combating constipation when developed that require long periods of time. Mild laxatives, and even certain kinds of enemas at times are lesser evils, but most important is prevention, the education of children as to regularity of habit in defecation, together with dietary aids and energetic treatment by hygienic methods in the early stages of the disease.

May I presume to bring but one other subject to your attention, the subject of bodily statics, a great problem that finds only desultory consideration in a general superficial way on the part of most persons, but that ultimately concerns every living person, whether sick or whether thinking that they are well. Apropos, perhaps it might be observed in extenuation that it is hoped that the picture drawn is not too depressing. If most of us are not entirely well, we have been thus for long periods of time, and everyone else is in the same boat. Glasses and false teeth are not incompatible with happiness. It should not depress us because we hear of facts that perhaps we had not previously appreciated. Then perhaps, too, as has been suggested, no doctor is normal, but sees only through the light of his vocation. Somebody once said that the doctor thought everyone was sick and the Christian Scientist thought that no one was ill. This as you will.

With regard to this matter of bodily statics. By statics, of course, is meant the architecture of our bodies; our peculiarly personal figure and structure, that makes for individual carriage, our own way of standing and holding the shoulders, a certain form of feet, a certain balance of the pelvis and above all a certain form of spine. Only in young, and even then, in very few persons, is there a highly admirable static condition. We see only occasionally beautiful bodies in which the spine is of lovely curves, the poise is exquisite and there is that grace and ease of movement that we love to contemplate. As we get older these are gradually lost, the shoulders droop, the spine undergoes various abnormal curvatures and becomes set in them, the arches of the feet often break and the figure is, at least in a measure, lost. Now, with these modifications of figure go muscle strain. We stand erect because muscles hold us in that position. If one is shot while standing, the muscles instantly relax and he falls. With changes in the bony framework occur muscle strains which result in fatigue, muscle spasm and pain. The vast majority of backaches are secondary to such malstatic states, spinal curvatures, ill balance and the like. Flat feet from broken arches form another illustration. The condition results in muscular strain and pain in the legs, thighs and back. Ill posed feet throw the entire figure out of balance. One cannot begin to adequately accentuate the importance of these things, and to sufficiently urge the necessity for bodily care, not through straining athletics in youth, but through moderation and well considered exercise, rest, proper nutrition, and proper clothes, the most important feature of which is footwear.

To retrogress: One feature that led to the previous assumption of falling viscera, displaced stomachs and the like, as a symptomful disease, was this problem of bad statics. Stomachs of low position may be considered abnormal in this that they often tend to throw the body out of balance and consequently there is generally relief afforded by proper corseting and support; not through elevating the stomach itself, but by thus taking unnatural weight and strain off of the incapacitated and overburdened back.

There is no question but that we have made considerable strides in medicine, even though we are in no position to, in any manner, pat ourselves on the back. We have made but a start; we have come to properly appreciate our ignorance, and let me recall that there are as bright minds in medicine as there are in any other line of work. We are learning to care for ourselves and to successfully combat many diseases. What does the future hold for our descendants in the centuries to come? The obvious view would be that of a highly beneficient situation, in which the cure of each disease would be readily available and in which hygienics, rational diet and proper living generally, became universal practices to an altogether happy ending. Not to be pessimistic, there is a more depressing view and one that will surely demand its solution. We are learning a little, though even now perhaps too much, in that there is danger of interfering with those great biological laws that resulted in our present being through the cruel doctrine of the survival of the fittest and the evolution of species. I hesitate to develop this subject, yet we must voice the truth as we see it, and in the end, there will be nothing gained by seeing as through a glass darkly. Before we can reach the solution we must appreciate the cause. Modern medicine in its trend is even now tending, and in the future will undoubtedly much more tend, to preserve inferior and less resisting types of persons to procreate their kind. We take pride in our low infant mortality, but it implies from a purely impartial standpoint the saving of less desirable types to reproduce themselves. Pretty girls sell tuberculosis society tags on the street corners and thus help to save many tuberculosis patients, and so do God's speed, we say; but dare I ask, what of all the tubercularly susceptible people that they succeeded in saving who will tend to reproduce their kind? It is an unattractive view; but let me proceed until we may at least sense a solution. We see more and more frail children survive, many desperately sick people recover through skill in diagnosis and treatment. We have considerably increased longevity, but what of the future? Is it not possible that we tend to develop an inferior and less resistant type? Ease of living, lack of those hardships that through elimination developed primitive people are also factors to the same end. Physically the race seems not in decadence but constantly more athletic. But this may be a temporary phase. Anthropologists tell us that there is evidence to the contrary. That the little toe and the third molar teeth are being rapidly lost. They inform us that our bones are becoming constantly lighter in proportion to body weight. That the skulls of newborn children, with the growing premium on brain development, are increasing in size to such an extent as to suggest that in a thousand years more a natural birth will hardly be possible. Are we not interfering with vast biological laws in our enthusiasm? What is the alternative? A let-alone policy? Never, our moral sense—we now have developed a moral sense—will not permit it; it is unthinkable. What then? What solution can there be?

There is such a subject as eugenics, a subject that teaches the doctrine of the modification of our physical being, and even more than our physical being, through proper control of the offspring through control of the parents. This solution is adequate to the situation, and if we are to survive, if the superman is to come, it and it alone may suffice. It need not, in any way, interfere with our present beliefs or rituals. It need not in any way offend moral sensibilities. It may come best through education and elevation of standards. We may even now aid through the instruction of our children, difficult though this be. There are present tendencies in this direction as expressed in the question of personal health before marriage. But somehow, somewhere, some such process must become active if humankind are to survive and carry on to that ultimate and unknown fulfillment; for believe me whether we will see it or not, we are in danger through transgression of those great and pitiless laws of nature that have led to our being.

It is to be hoped that these not very orderly suggestions have not been along too radical lines. Perhaps it was attempted to indicate, as suggested in the beginning, that our individual interpretations are expressions having origin in different sources, and lead to different conclusions. That if we would labor in the interest of culture and service we all must strive to see things, including each others' opinions, broadly and charitably—and let this be its extenuation.

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THE NATURAL HISTORY MUSEUM MOVEMENT IN ST. LOUIS

AUGUSTUS G. POHLMAN

Issued April, 1924

THE NATURAL HISTORY MUSEUM MOVEMENT IN ST. LOUIS.*

AUGUSTUS G. POHLMAN.

It is a difficult matter to speak on the same topic time and time again without exhausting the possibilities in the presentation. It occurs to me, however, that certain aspects of the proposition of the establishment of a Natural History Museum may be profitably analyzed. I submit my own ideas on this subject for whatever they are worth, and hope they merit a rather free discussion. It has been maintained that variety is the spice of life, and if this be true, variety is what we are after because the conspicuous outstanding feature in the Natural History Museum Movement in St. Louis is its lack of movement. I have indicated in a previous address that we possess the chrysalis of a museum which is ready to break from its too prolonged hibernating period to emerge as a beautiful, competent, active organism if only proper conditions may be brought about. Let us depart from the accepted rules and regulations of a paper of this kind and frankly ask ourselves a few questions. What is wrong with the environmental conditions, that an organization dedicated to an established and valuable cultural quantity, meets with nothing but indifference and resistance? What is wrong with a Natural History Museum that it is not acceptable to the people in general? What is the matter with us, the members and friends of this movement, that individually and collectively, we can do no more than maintain our chrysalis in its dormant stage? The time has come for

***An address delivered before the Museum Section of the Academy of Science on October 17, 1923.**

an inventory, and inasmuch as we are all of a scientific turn of mind, let us consider certain fundamentals which seem to lie at the root of our troubles before we attempt to answer the questions. Without a diagnosis as to the causes of a comatose condition, we are rendered all the more helpless in the treatment which might be applied and the prognosis becomes more guarded.

We all of us realize what is meant by natural selection, and throughout the entire biological world we see evidences of limited adaptation to the existing environment. There is probably no plant or animal which is perfectly adjusted to its surroundings because both are subject to certain more or less definite variations. The laws of natural selection operate almost entirely through selective breeding and the living form, having once been forced in a given direction, presently tends to overdo the very thing which made the survival possible. It attains a sort of hair-trigger balance to the conditions about it, and the more perfect the adaptation, the relatively less change in the conditions required to eliminate it. The sport-form tends to disappear and the throw-back gains the ascendancy and things go back to where they came from, or snuff out. I need only call your attention to the structural adaptation in the rodent in which the incisor teeth grow throughout the life of the animal. If now this animal is placed under conditions where the teeth may not be ground off as they grow, then these same teeth through their growth will finally lock the jaws of the animal and it may starve to death in the midst of plenty. Dave Harum's suggestion "that a reasonable number of fleas is good for a dog" contains more sense than nonsense.

We marvel at the conditions which made possible the enormous reptile forms of geological times. We are not surprised that these animals do not exist at the present time. They thrived when the earth was younger and great cataclysms occurred which buried them, and other cataclysms came about which brought them up out of the sea and made them accessible for study in the rocks. Just so we look into the palaeontology of the horse and trace it from the tiny fox-like animal to the wonderfully adapted variety we have today. One might say that the horse has attained the peak of his physical possibilities. But we know practically nothing concerning ancient man. Perhaps as Wells and others have suggested, he was lost in a flood and when the sea broke through Gibraltar man was almost completely wiped off the face of the earth. Perhaps millions of years from now when the Mediterranean basin rises, like the dinosaurs, the structure of primitive man may be carefully studied. However, we are entitled to guess this much; that man attained the physical peak of development long before history was. We have with us today physical examples that might vie, measurement for measurement, with the Cro-Magnon folk who perhaps disappeared from the earth many thousands of years ago along with the woolly mammoth, the giant elk and the sabre-toothed tiger. This is a point I wish to emphasize because it is essential for you to get the viewpoint.

If man attained his physical perfection long ages ago, in what manner did his survival differ from that of the animals? In other words, having passed his physical peak he ought to slump, decline or be eliminated by the forces about him. The answer may be summed up in the word "intelligence." It is not my purpose to define for you what intelligence may mean. It may, or it may not, mean the ability to discriminate right from wrong. The intelligence manifested itself in the ability to modify the environment—to change the conditions to suit. Had it not been for this very thing, man would probably have been eliminated myriads of years ago. Man began to profit by past experiences in dealing with situations of the present, and began to look into the present conditions with an eye to the future. Man, in other words, does not live in the present tense alone, driven along by instinct, but he knows of the past, and he knows of the future. Those people who live from day to day, pass as nearly an animal type of life as it is possible for a human being to accomplish. As one of my colleagues puts it: "Every man should have three good reasons why he is alive, and any man can give two; one, he was born alive, and two, he has not passed away. A third reason for living would worry some folks." I realize this is an insulting thing to say. The truth is not always pleasant.

I cannot trace with you anything more than enough of a sketch to build on, and I therefore will ramble along in the same strain. Let us assume a group of human beings banded together by a gregarious instinct or for the purpose of protection. What is the first thing a community of this sort must have? It must have rules and regulations governing the activities of the individual members so that the colonial life will not work at cross purposes. Further, it must delegate, or someone must assume, the authority to see to it that the rules are observed. In the olden days it was probably the strongest man who ruled, and as the community became more and more complicated and men used their heads more and their hands less, the craftiest strain got the upper hand. The next thing which happened was the development of some sort of measuring stick through which the value of an individual to the community might be determined because all men could not barter and all men were not equal. So with a medium of exchange, and with a class distinction of those who possessed, as opposed to those who did not possess, we can very readily construct an increasing complexity in life. Men became ambitious for power, for distinction, for value. Just as an animal may quite unsuspectingly over-develop his adaptation in reference to his environment so man may have or has over-complicated the environment in which he lives. The measuring stick of the efficiency of any living form is to be calculated on its viability. In spite of all of the modifications of rules and regulations of the game of life as worked out through thousands of years of experience, we are attaining a point in our civilization where our self-created environment is becoming so complicated that we are threatening to snuff ourselves out. It has happened before. It will happen again. We are passing our mental peak. We do not study the conditions of the past in reference to the present. We do not study the conditions of the present in respect to what is to be in the future. We assume no responsibilities to our antecedents. We do not take into account what will become of our descendants—if indeed there be such. We chase our rainbows of fancy not for the interest and the joy of the chase; not that it will bring happiness; or that it will better our fellowman, but for the pot of gold which is concealed under the far end. And think what this gold will buy in terms of political power; of social distinction; in ease and pleasure of living. We would buy something with it that may keep out of the picture anything pertaining to a yesterday and anything which considers a tomorrow.

We worship at the most convenient shrine. And we recognize service? We all realize the value of whole-hearted disinterested service. Indeed we do! How cheaply can you buy it? And the pathetic thing is we are cheating ourselves out of the best things in life because we cannot or will not look at anything but today.

The immediate results you see about you. Gone are the days when the little boy listened to fairy stories at his mother's knee. Gone are the days when grandmamma gave the little girl her first lessons in knitting. We send our children to school that they may be made into hothouse plants and into walking dictionaries of information because the school system is a most excellent one. Excellent in that it encourages reasoning in the child at a time when it is largely memory, and seeks to educate a memory when it ought to be taught to think straight. If the survival of man has been determined largely by his appreciation of what has occurred in the past and his ability to look into the future, might it not be well to see to it that the educated man appreciates the factors which go to make up the environment which must be modified to render possible his survival? We seek to justify the usefulness of our education. We publish statistics on how much more a college graduate can earn than one who has only finished high school. Are we really concerned with the happiness and the reasonableness in a life which a knowledge of cultural subjects carries with it? Twenty years ago a certain college president went out gunning for students that his educational institution might show the increasing thirst for learning before a legislature. Today the same college president talks about the unwieldiness of the overgrown college and seeks to keep young people out. Think of the long time a child must spend under the enforced artificialities of life before he attains his legal age. Think of the daily growing resentment on the part of parents that children imitate them. Think of forming organizations which boast of the requirement that each of the members shall accomplish one kindly, friendly act a day. This is indeed an artificial environment and the condition is becoming increasingly serious.

The present day individual is not particularly interested in constructive work or in constructive thought unless it will produce immediate returns. What he wishes to see are results and they are about him everywhere if he will but take the trouble to look. Do we not pay fabulous sums of money to keep us amused when anyone who gives the proposition a moment's thought must realize that the things worth while are the things which are worth working for? What reasons would you advance for the establishment of an art museum, if we did not possess one? Can one not see the wonders of the world, normal and abnormal, at the movies? Do we really enjoy our walks along the streets teeming with danger from multicolored and ubiquitous automobiles busily transporting people from some place which bores them to some other place which may bore them less? Do we not spend millions to be entertained at vaudeville houses and musical comedies when our symphony goes begging for funds? And when the call comes for financial assistance what do we find? We find the Chamber of Commerce sends out teams to raise funds because *strangers* will not come to town and spend money; *people will go elsewhere to buy* and the merchants will lose; we will not advertise our city so successfully! I would like to see just a little more emphasis on the idea that a well-subsidized symphony is a cultural asset to the *citizen of* St. Louis.

Years ago we used to drink plenty of mud with our water and finally a method was discovered (and as little paid for the discovery as possible) whereby the water could be rendered clean and palatable. Perhaps it was suggested at this time, too, that real estate values would not rise; that merchants could not make so much money; that the world's fair could not be brought to town! Let us hope that the propaganda also concerned the citizen of St. Louis, and included the possibility that he and his children and his children's children might be happier and healthier.

If we possessed no art museum, we would have difficulty in showing cause why one should be established. If we had no Missouri Botanical Garden to brag about, we would not know, even as we do not know, what this institution is all about. If we had no public library, we would have great difficulty in convincing our citizens that we really needed one. See the number of available magazines and see how many of them contain pretty pictures! The chief difficulty with the Natural History Museum movement is that our museum burned down sixty years ago. If it had not burned down, we would probably have as fine a museum in St. Louis as is found in any large city in the country.

That, I believe, answers the first two questions. We have attained so artificial a condition of environment that it will take an extraordinary circumstance and a number of extraordinary individuals to float the proposition. Second, what people don't know does not worry them! Nobody knows much about a Natural History Museum! Why have one at all? Of what use is it anyway?

Now, where do we fall down? We fall down because our organization is just another one, and there are too many already. What is there in our educational system that stimulates a love of nature? Why should anyone be interested in a cow when they use canned milk? Why should there be an appeal in anything which is natural at all? But let us not forget that all of the artificialities of life are based upon natural resources. Without the cow, there will be no canned milk! Unless someone studies the life history of the silk worm, my lady will have no silk stockings! We do not raise our wheat under glass, and you cannot construct desirable hardwood floors out of reinforced concrete. We are not educated to the appeal of the real thing. We crave to see a green ostrich or a pink elephant! Why take the trouble to show the clam with the pearl in place when you can see a whole string of near-pearls about almost any woman's neck?

There are some of us who are optimistic, and if we cannot make our appeal to the reasonableness of adults perhaps we can arouse the curiosity of the child. If we wish to get away from the artificialities of life, we can do but little with adults; their physical and mental habits are too well formed, but coming generations may profit if we can but make a start. With the start in the Educational Museum, why cannot this sort of thing be kept up?

I have fallen down. I have been accused, and rightly accused, of being unable to *sell* the proposition to the citizens of St. Louis. I have been unable to locate a single person who will put his shoulder to the wheel and help this good thing along. I don't even demand he be sincere in his motives. I have spoken before many organizations and each one has gladly subscribed to the sentiment that a natural history museum would be a desirable quantity. I can also see that we can have that charming sentiment from every single individual in the city directory and still maintain our larval museum in its comatose condition. I am not complaining, and I am not criticizing anyone but myself.

Some day we will have a museum. Some day, someone, somehow, will take pity on us and look upon the fire sixty years ago as a calamity, a loss which must be corrected before it is too late—if it is not already too late. All we can do is keep on trying and working with the ambition that if there is something radically wrong with present conditions, perhaps here is one thing which will help put thinking people straight. If we can just accomplish that much—put a few thinking people straight, it will be worth all the time, the money, the labor and the heartaches it has cost us.

This, to my notion, is what is wrong with the Natural History Museum movement. Nobody knows anything about a Natural History Museum in St. Louis and no one will see any advantage in first-hand information when second-hand information is so accessible. We want people to know things first hand, and a proper museum with a proper staff will make the direct appeal for the conservation of natural resources. It will stimulate a familiarity that breeds respect. It will encourage and develop the interest and attention of the one man in the thousand whom the other 999 will gladly follow. Let us introduce the element of truth into the artificialities of life that our children may gain a knowledge of the past; that they may realize and appreciate the possibilities of the future; that they may better understand the responsibilities of the present.

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THE BIOLOGY OF THE ROACH, BLATTA ORIENTALIS LINN.

PHIL RAU

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THE BIOLOGY OF THE ROACH, BLATTA[1] ORIENTALIS LINN.

PHIL RAU.

In speaking of roaches, Sharp[2] in 1895 wrote: "Although some species of Blattidae are domesticated in our houses and their bodies have been dissected by a generation of anatomists, very little is known as to their life histories." After almost thirty years, this void has scarcely been filled. The following study on the biology of the oriental roach was made in 1916 as a preliminary to the behavior studies that had been planned. Since it now seems probable that this work cannot be continued in the near future, it seems best to publish the data, although the investigations are not complete, and so partly fill a conspicuous gap in the literature of this group.

The common black beetle, or as it is more commonly called, the oriental cockroach, a native of the far east, has established itself throughout the world by the agency of commerce. It delights in darkness, and its flattened body is adapted to finding ready concealment in narrow crevices. Sharp[3] further says that "*orientalis* is gregarious, and the individuals are very amicable with one another." It seems to me that this condition is thrust upon them in the narrow confines of the cracks, rather than caused by their predisposition to amicability.

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[1]While this species is often referred to under the generic name *Periplaneta*, Mr. A. N. Caudell of Smithsonian Institution writes that *Blatta* is the well-established name for *orientalis* and should be used in publication.

[2]Cambridge Nat. Hist. 5:229.

[3]Loc. cit. p. 231.

The oriental roaches are nocturnal in habit, remaining within their dark abodes during the day, sallying forth under cover of darkness to seek their food, and, being fleet of foot, scurrying with astonishing speed to a place of safety in the event of danger. They leave in their runways the persistent "roachy" odor, which, according to Marlatt, comes partly from their excrement, but chiefly from the dark-colored fluid exuded from their mouths.

Cockroaches appeared very early in geologic time, some representatives appearing as early as the middle Silurian and many in the Carboniferous age. In all, about 130 species have been described from the Palaeozoic rocks of the United States. For millions of years the roaches have remained stable. This must be due to one of two causes: either the environmental conditions have remained constant, or the insect persisted immutable despite changed conditions. Undoubtedly the conditions have changed since the species took to feeding from man's larder, but since the insects are omnivorous, these changes may have been one of degree and not of kind. The roach has probably reached that stage of perfection where the habits are standardized. Variation is curtailed, because there is nothing to be gained by it; if variants should occur, they would soon be eliminated. The roach has survived through untold generations, whereas other species have suffered alteration or extermination. Moreover, there is no great difference between the present and the fossil forms in so far as their morphology is concerned. Early in the phylogeny of the race, they became omnivorous, probably distasteful to other creatures, fleet of foot, and fecund. That these adaptations were eminently successful is evidenced by the fact that the species has continued unchanged and has flourished through so many centuries.

While the cockroach is universally regarded as unqualifiedly loathsome, yet it offers its contribution to the welfare of mankind. Ealand[4] tells us that it devours bed-bugs with great avidity, and that in Russia *P. orientalis* has long been used in powdered form and in other ways as a remedy for dropsy, and in other parts of the continent the powdered medicinal form of *P. orientalis* is sold under the name of Tarakane, as a remedy for pleurisy and pericarditis.

Since roaches are universally regarded as vermin, it is natural that we should take it for granted that they are perpetually replenishing their population without regard to seasons. Careful observation soon leads to the discovery, however, that they, too, have their seasons, although perhaps not so sharply limited as are the life periods of those species that are obliged to conform to nature's demands without the protection and provisions which human habitations supply, even grudgingly.

Heretofore it has been thought that the roach requires several years to reach maturity. Sharp[5] says, in speaking of the black beetle of the kitchen, referring to observations carried on by himself and Mr. H. H. Brindley, that the growth accomplished in several months being surprisingly little, "it is therefore not improbable that the life of an individual of this species may extend to five years." In St. Louis, the life cycle of this roach from the hatching of the egg to the death of the adult is about one year. My notes show that in confinement all the adults die between July 1st and August 2nd, and

[4]Insects and Man, p. 281.
[5]Loc. cit. p. 229.

all those in their natural environment also disappear at this period. Very soon after that date one may, by very careful watching, find the young nymphs frolicking about sink and pantry. Toward autumn they reach a fair size of nymphal development and become conspicuous enough to once more attract the attention of the housewife. If they are captured at this time and kept in confinement, they become adult in May or June. This, of course, leads one to believe that the life cycle normally covers about one year. There is much misapprehension as to the length of the life cycle. Ealand says: "After the first year, moults take place annually."

Dates when nymphs transformed into adults.—Nymphs taken in August and September, 1915, and kept in large fish globes with plenty of food, transformed into adults (with one exception) the following May and June on the following dates:

Date	Males	Females	Date	Males	Females
May 8	1	--	May 28	1	1
12	1	1	29	2	1
15	10	3	June 1	2	3
16	1	1	3	4	1
17	1	--	5	1	2
18	1	--	6	1	1
19	1	--	7	1	--
20	2	1	9	1	2
21	2	2	13	1	3
22	4	--	15	1	1
23	3	1	16	--	2
24	1	1	July 29	--	1
25	1	1		—	—
26	2	1	Total	47	31
27	1	1			

Thus we see that their normal time for reaching adulthood covered a period of five weeks (the one straggler may reasonably be regarded as abnormal). It is safe to regard this as a typical sample under normal conditions, since the pests always live in houses in similar conditions. The proportion of sexes, 47 males to 31 females, agrees with the condition we almost always find in the insect world, i. e., a larger proportion of males.

Fig. 1. The cockroach *Blatta orientalis.*

Here, too, the mean date of emergence of the males is slightly in advance of that of the females.

On the authority of Riley,[6] Hyatt says the larvae of this species when hatched are brooded over by the mother. The mother roaches in my experiments gave no evidence of maternal solicitude. In fact, the data here-

[6] Insecta, 1890, p. 103.

with show that the length of time between the emergence of the young and the death of the parents was very brief and sometimes reduced to nothing.

There is strong dissimilarity between the sexes of the adult roach, the female having only rudimentary wings (see fig. 1). In the nymph stage it is hardly possible to distinguish the sexes. The roach reaches the adult stage after passing through a series of moults.

Longevity of the cockroach.—Notes were made on the length of adult life (from the time of transforming into adults to the time of their death). All of these roaches were kept in glass jars with ample food. Thirty-nine males lived from 14 to 64 days, and 29 females lived from 21 to 82 days, as tabulated below.

Longevity	Males	Females	Longevity	Males	Females
14 days	1	--	45 days	--	3
19 days	1	--	48 days	2	2
22 days	4	2	50 days	5	2
25 days	1	--	53 days	3	--
26 days	1	1	55 days	2	3
28 days	--	3	58 days	--	1
31 days	1	1	60 days	1	1
32 days	1	1	64 days	1	--
33 days	1	--	82 days	--	1
38 days	6	4			
40 days	1	1	Total----	39	29
42 days	7	3			

Thus we see that the average duration of life for the males was 40.2 days, and for the females 43.5 days. This difference is not great, but these few figures show at least that the females are inherently longer lived than the males, a condition that is often found in the insect world.

The data gathered in 1916 indicated that July was the natural period of death for the roaches, both those kept for observation and for the population at large. By August 2nd, all those in the jars had died, and simultaneously the adult roaches at large in the building had disappeared.

The housewife has a justifiable abhorrence of these creatures when they are adult; when thousands of nymphs infest her home, either she sees them not, or she bothers not about them, but the adults are conspicuous and at once arouse her wrath. Forthwith she hies her to the nearest chemist and gets some good exterminator; two weeks later she will in good faith gladly tell the merits of "XYZ" paste, and one cannot convince her that she spread her poison just at the time when the roaches were dying a natural death, and that they would have disappeared at that time of the year regardless of whether or not she spread her paste.

Number of egg cases deposited.—The female deposits during her lifetime from one to four egg cases. Fifty-five roaches were confined for the purpose of getting data on oviposition. The following table presents the data.

Egg cases.	Females.
1	8
2	19
3	19
4	9

The egg cases are not dropped as soon as they are formed, but they are slowly pushed out from the abdomen, and after they have been carried about for two or three days, they are finally dropped. I am inclined to suspect that the duration of the period of waiting is determined in greater part by inherent physiological conditions, and in a lesser part to the temporary environment, i. e., the dropping of the egg case is to some degree postponed until a place is reached where it may be deposited amid proper surroundings of moisture, temperature, seclusion, etc.

Age of females at time of first oviposition.—Records were kept of the lapse of time between the date when the female roach went through the final moult and became adult, and the day when she deposited her first egg case. These intervals were 8, 11, 11, 13, 14, 15, 18, 19, 22, and 24 days.

Thus the normal females in this series never deposited before they were 11 days old (the 8-day individual was virgin), and one deposited her first egg case at the age of 24 days. Averages, however, are of no significance in this case, since in all probability egg laying is closely connected with mating, and no records were kept of the time that elapsed between mating and oviposition. This oviposition occurred from the third week in May to the middle of June, but no correlation could be detected between the age of the female at first oviposition and earliness or lateness in the season.

Records were also kept on the number of days that elapsed between the various egg cases for 35 females. As mentioned above, each female deposits during her life-time from one to four cases; these, however, do not follow in rapid succession, but at the following intervals:

Roach Number	Days between 1st & 2nd	Days between 2nd & 3rd	Days between 3rd & 4th
1	6	15	--
2	12	--	--
3	8	--	--
4	11	--	--

Roach Number	Days between 1st & 2nd	Days between 2nd & 3rd	Days between 3rd & 4th
5	10	--	--
6	9	--	--
7	11	--	--
8	6	15	--
9	19	--	--
10	6	12	--
11	11	--	--
12	8	16	--
13	8	--	--
14	8	8	--
15	8	--	--
16	10	13	--
17	10	13	--
18	9	12	--
19	23	--	--
20	11	--	--
21	13	8	8
22	13	6	10
23	12	6	11
24	12	5	11
25	6	10	--
26	4	7	--
27	4	6	--
28	4	9	--
29	12	--	--
30	11	--	--
31	9	--	--
32	9	--	--
33	9	10	14
34	10	14	--
35	10	15	--

These figures indicate that there is no appreciable difference in the time required for the formation of the second, third or fourth egg case, and also that this interval is practically the same (except for a few cases) as the time elapsing between the last moult and the first oviposition, as shown on page 63. Both sexes were often kept together in the jars, and it is not known whether mating occurred more than once. The eggs were all fertile, but I suspect that these long lapses between egg cases are probably due to the maturation of the eggs, rather than a necessity of mating for each egg case. An interesting observation from the biological standpoint would be to test the fertility of the eggs in relation to one or more matings.

Period of incubation.—The period during which egg cases were deposited extended from the latter part of May to the end of July. The period of incubation seems unusually long. At the time of the emergence of the nymphs, all leave the egg case at one time, instead of the alternative of the emergence covering a number of days for each case. The following data on the period of incubation were collected on egg cases deposited from May 21st to June 11th:

Days	Number of egg cases	Days	Number of egg cases
45	8	52	6
46	7	53	6
47	3	54	1
48	1	55	5
49	1	56	4
50	3	61	1
51	8		Total----54

Thus we see all of these 54 egg cases (exclusive of the last, which might safely be regarded as abnormal), having a period of incubation varying from 45 to 56 days. The egg cases, as each was deposited, were placed in jelly glasses and kept in the third floor laboratory. It seems to me that, if temperature has anything to do with hatching, this should have accelerated their development, for it was much warmer in the attic in July than in the cellar where the eggs normally are laid.

Emergence of the young from the egg case.—When first I witnessed the hatching of the roaches, I was much surprised to find that their emergence is very similar to that of the mantis, *Stagmomantis carolina.* The roach egg cases are the well-known purses, the upper edge of which shows a ridge or seam. By one of those miracles which make marvelous every type of birth, this purse or capsule is pressed open at this seam at the moment of the emergence of the young, and the inmates are all released at the same time, after which, the pressure relieved, the capsule again closes and appears outwardly exactly the same as before. If one examines a number of egg cases previous to hatching time, and presses the ends together with the fingers in an attempt to open this seam, he will find them so tightly sealed that the case will mash under the pressure before this ridge will open. At hatching time, however, they will yield readily, and at the slightest pressure will open beautifully, revealing the two halves of the case, each with the row of about eight mummy-like organisms, perfectly white except the eye-spots, which are black, and all arranged in two precise rows, heads up. In about three minutes after opening the case, all will have struggled out, and they are at once extremely active. This reveals the fact that when the egg case is deposited it has no opening, and only at the time of emergence does the opening gradually form.

One often wonders, upon picking up an empty egg case, how it is possible for the sixteen young to have emerged without leaving a break in the case. The mechanics is extremely interesting. As in the Carolina mantis, all the eggs are deposited with the head nearest the opening. The eggs, being produced practically at one time, or at least within forty-eight hours, all develop alike. In this mummy stage preceding emergence, the caudal end of the body tapers, while the greatest development is about the head. Now with all of the enlargement occurring at the fore part of the body, which is uppermost, it is easy to see how sixteen enlarging fore parts would mechanically and gradually open the exit, and simultaneously all would slide out *en masse* and automatically the closure would come together again.

Some writers think that the young secrete a liquid which dissolves the cement in the seam of the capsule.

This process is not merely an emergence, but also a real hatching, for in the process each insect issues from its individual egg shell and also from the öotheca enclosing a number of eggs. One often finds the thin, white caps that cover the forepart of the insect caught in the seam of the empty case, where the emerging nymphs have left them behind. In addition to this cap each mummy is completely enveloped in a thin, brown, papery bag, the egg shell. It is very pretty to see, when one splits the egg case in two parts, the two rows of heads facing the opening, wriggling and writhing out of this paper shell, and to see the two rows of heads, face to face, gradually make their appearance. I have said that at this stage the insect is completely white save the black eye-spots, but I have discovered with the aid of the microscope that the three teeth of each mandible are brown and seem to be thoroughly chitinized, the only heavily chitinized part about the insect.

When this mummy is removed from this bag, the head is inflexed, the legs, antennae and mouth-parts pressed flat against the body, and the segments very distinct—in fact, the whole organism looks like head and segments, and not at all like the roach it will be in five minutes. Even at this stage the two cerci are very prominent.

The roach works itself out of the egg shell by a series of contortions, comes out through the opening and there sheds a white membranous cap, which, no doubt, is for the protection of the head. This frees its legs, and then the newly born roach clumsily walks away. This behavior is very much like that described for the praying-mantis.[7] Another irregular piece of semi-chitinous covering hangs from the tip of the abdomen, and this, I think, is the shed skin that bound the legs and antennae close to the body. With a few hard jerks this is left behind and the roach, for only now does it really appear as a roach, scampers briskly away. If the egg case is not artificially opened, it indeed seems like magic to see almost simultaneously all heads protrude through the opening, struggle for an instant to get the limbs free, kick the hind legs loose from the adhering skin, and again simultaneously scamper away in all directions, all in less time than it takes to tell.

In opening many egg cases I found all of them fertile and in the same stage of development. In one case, however, amid healthy looking organisms, were two eggs opposite each other, hard and brown, dead or infertile.

Number of young in each egg case.—Notes were made on the number of nymphs that hatched from each of 43 egg cases. This number varied from 12 to 18, as follows:

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[7]Trans. Acad. Sci. St. Louis, 22:1-57. 1913.

No. in each egg case	Number of egg cases	No. in each egg case	Number of egg cases
12	2	16	15
13	5	17	3
14	6	18	2
15	10	Total	43

It is at once apparent that the mean number at which nature aims is 16, and her deviations from that are not significant; even the mortality in embryo is surprisingly small.

Food of nymphs and adults.—During the period of observation an attempt was made to keep a record of food materials which they accepted. Soon, however, the list became so voluminous that it was apparent that it would be more brief and simple to list the things which they did not eat. This dwindled almost to nothing. They showed a preference for the softer portions of the food before them, and left the hard or chitinized portions, but otherwise they ate everything of a vegetable or animal nature, either fresh or decaying, which came in their way.

Cockroaches are undoubtedly attracted to their food by the sense of smell located in the antennae. Lloyd Morgan [8] tells us that if their antennae be extirpated or coated with paraffin, the roach no longer rushes to food, and takes little notice of and will sometimes even walk over blotting-paper moistened with turpentine or benzoline, which a normal insect cannot approach without agitation.

Enemies.—Dermestes larvae often infest the egg cases of the roach. Some large frogs of the edible variety

[8] Animal Life and Intelligence, p. 257. 1891.

escaped from a tank in the cellar one night; when they were recaptured and dressed the next day, the contents of the stomachs revealed an astonishing number of roaches in the large nymph stage. In nature the habitats of the frogs and roaches are so remote that this relationship can hardly be expected to exist. Some common gray lizards kept in the laboratory also readily accepted the roaches as food. A neighbor told me that her chickens greedily ate the roaches which she had caught in traps. Woods[9] says that the cockroach is a favorite food of many animals and the hedgehog is so partial to it that one of these animals is sometimes kept in the kitchen for the express purpose of destroying these pests. A young friend who is a nature student informs me that he fed roaches of this species to a pet garter snake.

Roaches seem to require a larger supply of water than do most species of insects, and they drink it with an evident enjoyment that is pleasant to see. Their food often becomes mouldy, and fungus growths of various colors, black, yellow, green or gray, cover it, but this seems not to affect them in any way, and no increase in the mortality could be noticed at these times. Very often, too, their food, especially the starchy materials, becomes covered with myriads of mites, *Tyroglyphus lintneri* Osborn (identified by Mr. H. E. Ewing), but even these do not affect the health or the mortality of the roaches in the jars.

Method of concealing the egg cases.—The color of the egg case as it leaves the abdomen is almost white. Sometimes the exposed part of the case becomes dark while it is being carried, so a newly deposited case may have every shade from white through a reddish pink to a red-

[9]Insects at home, p. 237. 1872.

dish brown. Eventually all change entirely to a reddish brown.

Although the adults and nymphs of the roach may appear in abundance about the house, the egg cases are rarely seen. The reason for this was discovered in the habits of those kept for close observation in the laboratory. In the great majority of cases, the mother very deftly conceals the egg case, either by depositing it in a crevice or by carrying earth and debris, sometimes for considerable distances, and with this and her saliva, daubing the new case until it is quite hidden from view. This is so stealthily done that I have never been able to catch her in the very act, but the result leaves no doubt that the act is deliberately and purposely done. Of course the insects in their native habitat have every chance to conceal the egg cases beyond all chance of our ever finding them; even in glass jars, with a limited amount of material with which to work, they succeeded so well that in a few cases I myself did not discover them until I had injured them in handling.

A large number of females carrying egg cases were at different times placed in the jars, together with a small amount of earth and rubbish, just to see what would be their course of action. Out of 90 egg cases thus deposited, 36 were deposited in some place which afforded some concealment, as crevices in bark, the cells of old wasp nests, under a bit of paper or, in a few cases, in slight depressions which, I was sure, the mother roach had made in bark or clay, expressly to fit and receive her öotheca. Many, if not the majority, of these were also daubed. Of those which were dropped on the bottom of the jars (this open space formed by far the greater part of the available space), 38 were well hidden by having been daubed with dirt and rubbish stuck on with saliva, and only 16 were left uncovered. It is only reasonable to surmise that the unnatural conditions of their life at this time and my frequent interruptions may have hindered the normal functioning of some of the mothers in so delicate a task as this, and while the mothers in confinement concealed only 82 per cent of the egg cases, in their own environment and undisturbed, they would show a greater per cent of efficiency. As suggested above, if the egg cases had been dropped by mere chance, by far the greater part of them would have been on the floor of the jars. In many cases they were found crammed into crevices that must have been really difficult of access, and in more than one instance, three or four lay end to end in the same cranny in the bark, when nooks were scarce. In some cases we know positively that the mud must have been carried at least three inches.

I repeat the assertion that the act of plastering the egg cases must be deliberately done. While these mothers were never caught in the act of this work, we have the interesting details of this behavior of an allied species, *Periplaneta americana* Linn., by V. R. Haber.[10] He says that at 2:50 a. m., the female began to scar and roughen the surface of a cardboard in the cage. She chewed and munched at the upper surface of the pasteboard until she had made quite an appreciable dent, not dropping the pasteboard on the bottom of the cage, but mixing the bits with a secretion from the mouth until all became a damp mass. At 3:30, she crawled forward over the scar with her abdomen bent anteriorly and ventralward, probing about with the protruding öotheca until she located the scar which she had just made. After several unsuccessful attempts at placing the egg case in the

[10]Ent. News 31:190-193. 1920.

scar, because each time it rolled off, it finally fell and bounced to the far side of the cage, whereupon she promptly ran down and located it on the floor. She cleaned it with her mouth-parts, coated its exposed sides and ends with a secretion from her mouth and then picked up loose bits of trash, with which she covered it. She even went so far as to try to cover it with a piece of paper. Girault[11] also found this habit of covering the egg case with mud or bits of wood prevalent for *Periplaneta australasiae* Fab.

The mating habits of the roach.—In the proper season, a sudden switching on of the light often reveals a pair of roaches in copulo; they are motionless, and are united with their heads in opposite directions. The mated pairs are found on vertical walls, as well as on horizontal surfaces, but always in the same position. While I have seen many mated pairs, and have seen some attempts at mating, it still remains a mystery to me how this position is accomplished; it must be through some intricate movements. Mating always or nearly always occurs in darkness, and it is most difficult to observe the manoeuvers of these shy creatures, although by timing the experiments and by switching on and off the lights, one can get good records of the wooing. The ardor of the courting male is not cooled when the lights are turned on, but the modest little mate usually walks away and breaks up the party.

In the preliminary movements the male gets directly in front of the female, but turns so his head is away from her (so that the two are in single file), with the rear tip of his body directly in front of her face. He then walks backwards, pushing his body underneath hers and at the same time lifts his wings and holds them vertically,

[11]Ent. News 26:54. 1915.

thereby exposing the dorsal segments of his abdomen. Sometimes a feeble attempt is made to flutter these vertical wings in a way that suggests coquettishness. When he has partly inserted his body under her, she slowly walks on top of his back, touching or feeling the segments of his abdomen with her jaws and palpi. The cerci of the male are protruding and his clasping organs extended and opening and closing like a pair of tongs, in his attempt to grasp or feel segment after segment as she crawls forward over him or as he crawls backward under her (sometimes it is difficult to say just which is really happening). These movements continue, and just when one expects a culmination, the female breaks away or the male makes a false step and the pair separate. There must be some very interesting contortions occurring before he makes the connections and faces about completely from backing under the female to facing in the opposite direction, and it is probable that many attempts are made before this intricate task is accomplished. I hope some day, with better technique in the way of light regulation and mirrors, to be able to get the details.

There is actual courtship on the part of the males, and there is actual rivalry between them, as will be seen from the following experiment. On June 2, at 11:35 p. m., I placed 9 chaste males about two weeks old (since they had become adult) with a virgin female. Five minutes later, upon switching on the lights, I found the female had crouched under a bit of bark, and at the end of ten minutes she had already mated with one of the males, and several of the others, walking high up in the air with legs outstretched like stilts (an extremely unusual position which might be a way of trying to attract the attention of the female), were pestering the pair. One male in particular seemed to be biting the pair apart, and when I examined the spot after he had left I found that he had bitten away a large portion of the wing of his rival. I examined them at intervals for an hour, and found the pair still in copulo; the next morning they were separated, but there must have been some rivalry between the males, for two others had the wings badly bitten away. In another cage containing one female and four males, similar rivalry occurred; the female was passive while the males "walked on stilts" and protruded claspers. After some little display, three of these males retired and left her to the other suitor, which pursued her for fifteen minutes before he attempted to back under her.

C. L. Turner[12] says the process of copulation in the cockroach is so rapid that the details cannot be followed; it can only be said that the male shoves his body under that of the female, and accomplishes the transfer of spermatozoa in a few seconds. All those which I observed were much more deliberate, and in certain instances several hours were spent in actual mating.

I have recorded[13] very similar courtship behavior for the wild roach, *Parcoblatta pennsylvanica* DeGeer, but here in the only case observed the female assumed the aggressive role.

During the night males often go through mating manoeuvers with other males.

Exudation.—In working with adults one soon notices at times a gathering of a thick, milky jelly on the ventral surface that seems to ooze out at the lines of demarcation of the last two segments. This is an almost transparent, slime-like substance of sufficient gumminess to

[12]Ann. Ent. Soc. Amer., 9:122. 1916.

[13]Trans. Acad. Sci. St. Louis., 24:57. 1922.

hold itself together for many days, and is very noticeable on the black backs of the roaches. Just exactly where it comes from or what its function is, I do not know, but it probably oozes out from pores in thin chitin at the joints of segments and probably functions in some way in the mating or reproductive processes. This material was never seen to gather on the bodies of the males or on the mated females, but only on the virgin females. It is not wholly accurate to say that the mated females never showed this secretion; I should say, rather, that this material did not appear on the bodies of hundreds of females caged together with males, but at the same time in a group of virgin females that were segregated, almost all of them had varying amounts of this slime that exuded from the dorsal folds of the last few segments.

Miscellaneous activities.—Roaches are negatively phototactic and positively thigmotactic. Writers generally agree that roaches are gregarious, but it seems to me that their gregariousness has more or less been thrust upon them; being negatively phototactic and positively thigmotactic, and with large numbers of them seeking the same environment in limited space and hiding places, one can see how easy it is for the roach to appear as gregarious, but there probably is no more social tendency in the life of the roach than in any other member of the Orthopterous group.

While the roaches are dark-loving creatures, there is a behavior that indicates a response which is so aptly called differential sensibility. This can be tested by suddenly lighting up a roach infested cellar. The creatures run frantically until they come within the shadow of a post; there they stop short, and may easily be picked up. They seem certain of safety when in this darkness, although what they respond to is not real darkness, but only a less light condition. In the same way, I have seen roaches escape into crevices; when their bodies touched the crack they were satisfied, even though they were exposed to full view in the light; their condition of positive thigmotropism satisfied their feelings in the matter of protection from danger, and they did not venture deep into the crevice. Here, however, it seems that light and sight were factors that prevented me from picking them up, for when attempts were made they crawled deeper into the crevices, whereas in the dark shadow on the floor an attempt was seldom made to escape because the roach could not see my approach.

Roaches are very sensitive to odors or air conditions. One may handle the jar without disturbing the inmates if the jar is covered, or one may even remove the glass cover and come very near to look in if the breath is deflected, but to breathe, even gently, down into a jar at once creates a panic among the roaches. This simple test shows them to be susceptible to odor or air vibrations more than to sight.

Their coming out of hiding does not seem to be regulated entirely by the quietness of the place. On many occasions I have found, when a house had been closed for several hours, roaches were out to feed as early as 8:30 or 9 o'clock; on other occasions they may be found out foraging when the room has been darkened only a few minutes, when the noises of the city have by no means subsided. On the other hand, during the night when everything is quiet and one expects them to be out in abundance, one may find few or none. It seems they feed as early in the evening as possible and then retire.

I have never seen male roaches use their wings for flying. I have thrown them up in the air; they seem to have no control over the fall; they did not even open the wings to act as a parachute, but turned many somersaults in the air and hit the earth with a thump. The males can, however, make their escape by backward progression as rapidly as by traveling forwards.

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NOTES ON THE STENOMORPHIC FORM OF THE SHIPWORM

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The term stenomorph has been given by Dr. Bartsch (Bartsch, 1923, p. 330) to those specimens of shipworms which are abnormal in being dwarfed, although they may be sexually mature. Dr. Bartsch discovered the fact that this form is frequently found in small pieces of wood and inferred that it is caused by the cramped habitat of the individual. A study of the stenomorphic specimens found in the test-blocks placed by the Committee on Marine Piling Investigations of the National Research Council (Clapp, 1923, p. 31) has added further evidence of the conditions which cause this peculiar form.

The shell of the stenomorphic specimen (pl. 4, fig. 1) may generally be distinguished from the normal specimen of the same species by its smaller size and greater shell thickness, as well as by the proportionately greater number of denticulate ridges on both the anterior and the anterior-median areas of the shell. The internal blade or apophysis is greatly broadened and strengthened (pl. 4, fig. 2). There is, however, no sharp dividing line between the stenomorph and the normal specimen of the same species. Many large specimens, with tubes 250 millimeters or more in length, show traces of stenomorph characters in those portions of the shell last secreted. There is a well-graded series between these large, nearly normal specimens and those typical stenomorphs of the same age which possess tubes only ten millimeters long. In the typical stenomorph the auricle is entirely lost, being overlaid by the anterior-median area, since the denticulate ridges of this area completely cover the entire median area and also the auricle to its posterior edge. The anterior area is also proportionately large, the denticulate ridges of that area being added to its ventral edge until it is nearly as large as the anterior-median area both in length and in height. In a young normal specimen of *Teredo navalis,* the ridges of the anterior area are approximately one-fourth the width of the intervening spaces (pl. 4, fig. 3). In a typical stenomorphic specimen of the same species and of the same size, the denticulate ridges of the anterior area are so closely crowded that the spaces between the ridges are reduced to mere threads (pl. 4, fig. 4). This dwarfed form, while the same age as a large normal individual, may be but one-tenth of its size. The embryos in the gills of a sexually mature stenomorphic specimen are much less numerous than are the embryos in a normal specimen of the same species, but in all other respects the embryos are identical.

At many of the places where test-blocks have been placed by the Committee on Marine Piling Investigations, these stenomorphic specimens are frequently found in the wood, and since the blocks used in 1922 were small (2 inches by 4 inches), it was thought that the abnormality was caused by the cramped quarters. As Dr. Bartsch states (loc. cit.), they are frequently found in laths and other small pieces of wood, but that some factor other than the size of the wood enters into the result, is shown by the fact that laths and small pieces of wood frequently contain large and perfectly normal specimens. For example, *Teredo navalis* causes considerable damage to the wooden lobster pots in the waters south of Cape Cod. The laths of which the lobster pots are made are often completely riddled in a few weeks. The number of stenomorphic specimens in these laths is no greater proportionately than one finds in heavy piling and the average size of a larger number of specimens removed from the laths is the same as that of specimens removed from big timber. Also, large blocks, made up of many shingles bolted more or less tightly together (Mark, 1924, p. 266, footnote 3, p. 268, fig. E), were placed at fifty or more stations from Massachusetts to Texas. In some of these shingle blocks, stenomorphic specimens occurred, but in the majority the specimens were not stenomorphic, but nearly or entirely normal. Because of the fact that the average shipworm will endeavor to avoid crossing a large crack or open area in the wood, as long as progress is possible in some other direction, many of the shipworms in the shingle blocks made more or less of an effort to remain within a single shingle, the effort depending entirely upon how firmly the shingles were bolted together. When the specimens entered the thicker end of the shingle and advanced with the grain of the wood toward the thinner end, this effort to refrain from crossing to the adjacent shingle, resulted in a peculiarly abnormal form, in which the tubes are excessively attenuate. Many of these specimens were found which had attained a tube length of 400 millimeters in three months, but, owing to the thinness of the wood, had increased the diameter of the tube very slowly. The anterior ends of many of these long tubes were frequently but five millimeters and occasionally only four millimeters in diameter. The shipworm is able to contract its body into one-half of its normal length. The body is firmly attached to the wall of the burrow only at the extreme posterior end. In an effort to locate thicker wood an individual may occasionally withdraw its shell and the anterior portion of its body from the anterior portion of the tube, forming a new tube in a different direction. At the point of separation from the original tube a diaphragm is formed completely sealing the abandoned tube. This operation may be repeated several times by a single individual (pl. 5, fig. 3). Tubes of normal specimens of the same species which are 400 millimeters in length are approximately twelve millimeters in diameter at the anterior end. This abnormal form which occurs in thin wood, however, possesses none of the characters of the stenomorph. The thickness of the shell, arrangement of the denticulate ridges and the proportionate sizes of the anterior and anterior-median areas, being the same as in normal specimens, the abnormality caused by the thickness of the wood can be seen only in the excessively narrow form of the tube. The large proportion of abnormal specimens with attenuate tubes and the small number of true stenomorphs found in the shingles, would tend to show that the stenomorph characters are not caused by the size of the wood.

Also, many of the small test-blocks used in 1922 contained in one portion of the block many hundreds of stenomorphic specimens, while in another equally large portion of the block there were only relatively a few normal specimens of the same species. For example, small test-blocks from Galveston, Texas, contained for several weeks during the summer of 1922, in one-half of the block, hundreds of specimens of stenomorphic *Bankia gouldi*, few being more than twenty millimeters in length, whereas in the other half of the block there were always two, three, or more large normal 200-300 millimeter specimens of the same species. Furthermore, at the same locality the increase in the size of the test-blocks in 1923 to 4x4x6 inches did not change the result in the slightest degree, the proportion of stenomorphs being as great and the average size of the stenomorphic specimens being the same in the large blocks as in the small. Also, several of the numerous specimens of piling received from various localities on the Atlantic Coast, some of which were 18 inches or more in diameter, showed the same stenomorph form, not separable from those found in the small test-blocks.

From the above facts it is evident that the size of the wood is not necessarily the deciding factor in the production of the stenomorphs, for if it were, stenomorphs would not occur in large piles where plenty of wood remained unoccupied. In a great majority of the pieces of wood containing stenomorphic specimens which I have examined, I have found that the conditions at the time of the attachment to the wood of the embryo, were apparently very favorable. Many embryos entered the wood at the same time, frequently thirty or forty to the square centimeter. A large majority survived, but many specimens, owing to the fact that some of their neighbors entered the wood slightly earlier, or were more active in boring than they, soon found themselves unable to advance in any direction, for the reason that they were completely surrounded by the tubes of other specimens. The shipworm will never break through the partition of wood, however thin it may be, which separates it from a neighboring tube, whether the occupant of that tube be living or dead. These confined specimens continued to live for as long a period as those more fortunate individuals which were not checked in their growth. Since it was not possible for them to increase the length or diameter of the tube or the size of the shell, the only noticeable activity was in the regular addition of denticulate ridges and an increase in the thickness of the shell, this peculiar growth rendering them almost unrecognizable. In view of the fact that the shipworm is supposed to be able to obtain more or less nutriment from the wood into which it bores (Dore and Miller, 1923), (Harrington, 1921), it is interesting to note that the stenomorphic specimen, at least, is not dependent upon the wood for food, for living specimens of stenomorphic *Teredo navalis* have been found with a total tube length of only ten millimeters and yet with a known age of ten months. A normal *Teredo navalis* during the active season, will form a ten-millimeter tube in less than two weeks time. That the animal of the stenomorph should continue to produce denticulate ridges when there is no more available wood upon which the denticles can be used, is even more interesting.

I wish to express my appreciation for the assistance which has been given to me in my study of the shipworms at the Massachusetts Institute of Technology, through the kindness of Professor Samuel C. Presscott. Excellent laboratory facilities, photographic apparatus, etc., have been freely placed at my disposal.

I am also indebted to Mr. Nelson M. Fuller for the excellent photographs and for other assistance in my work.

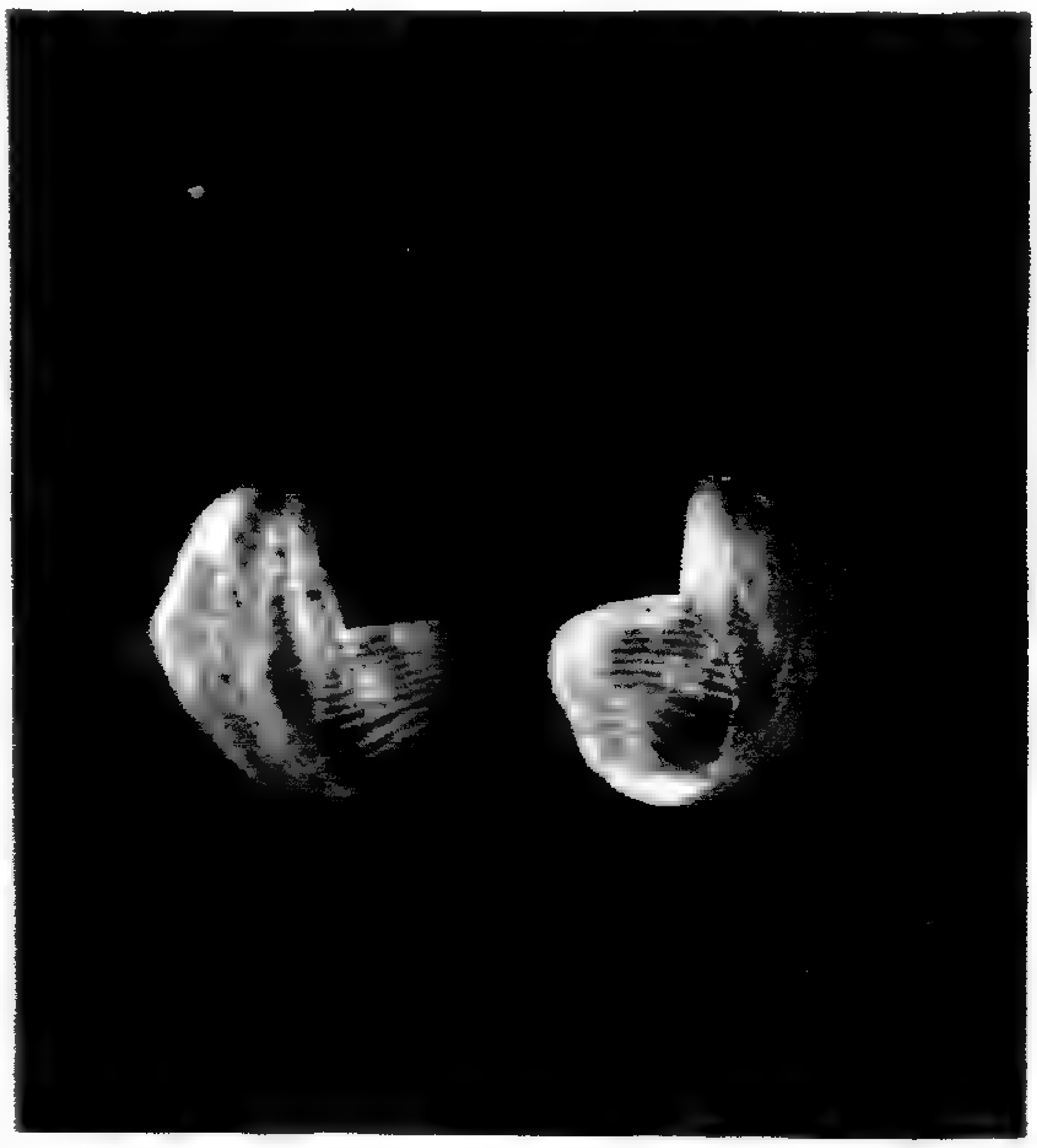

FIG. 1

FIG. 2

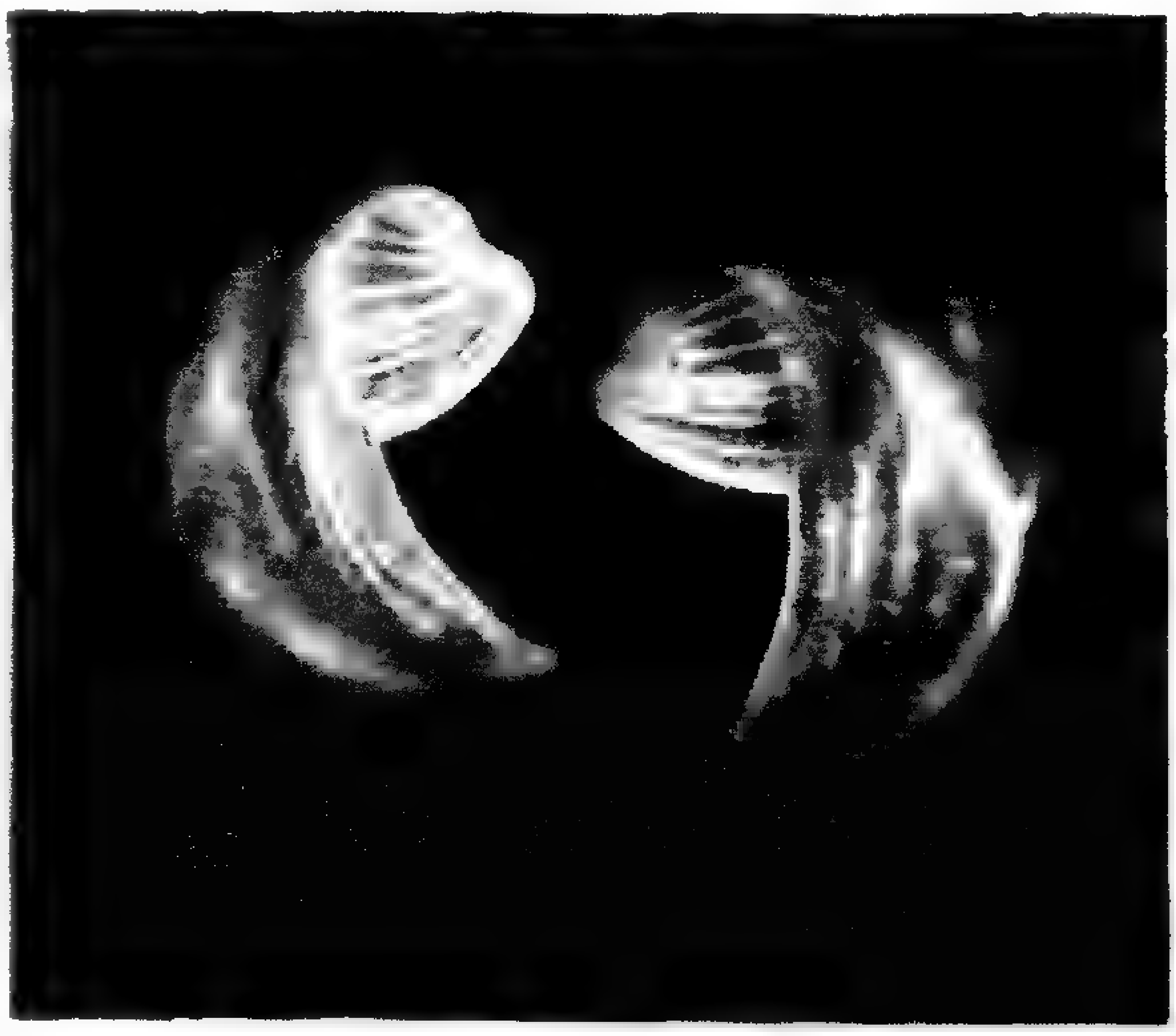

FIG. 3

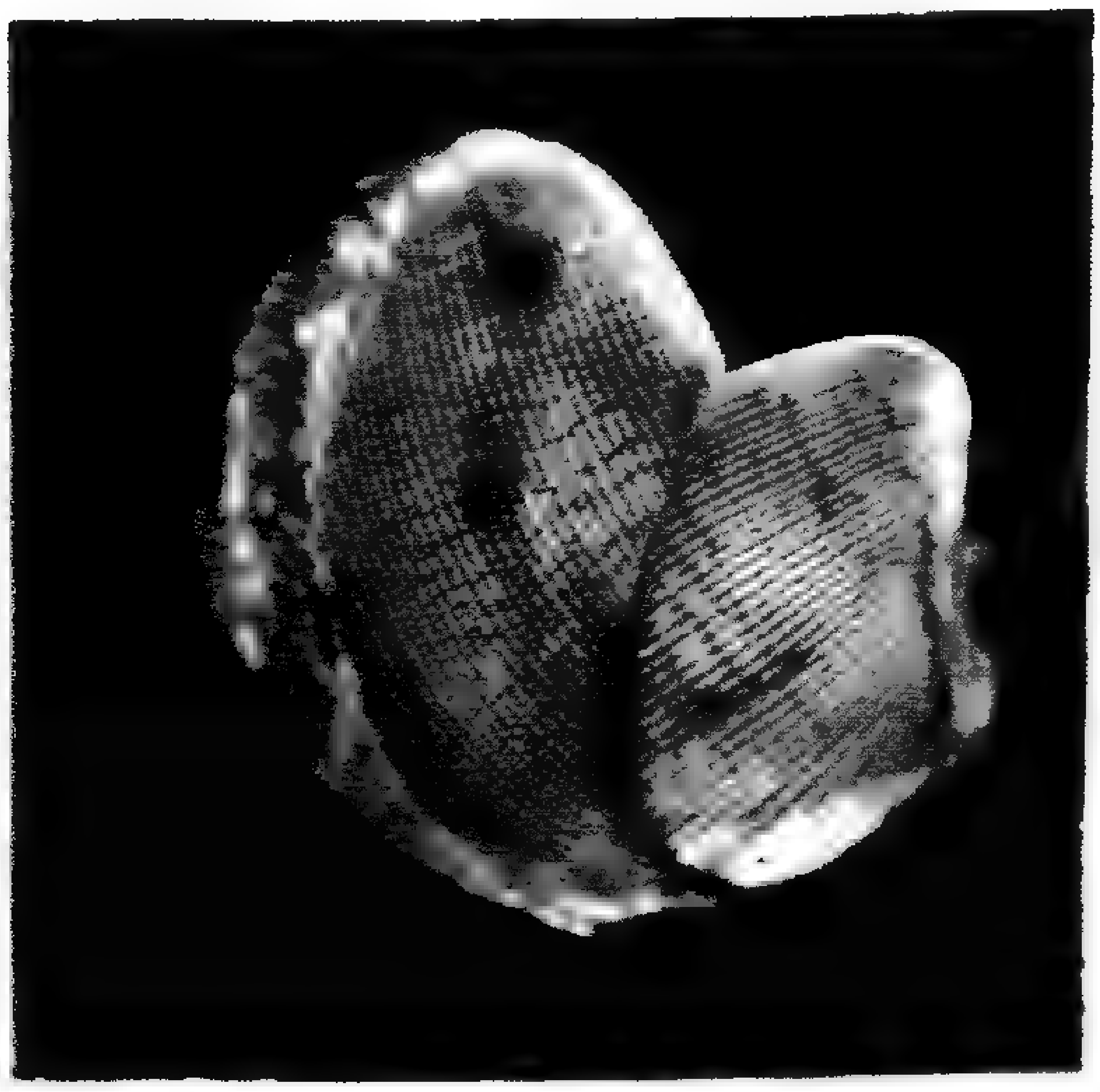

FIG. 4

FIG. 5

EXPLANATION OF PLATE

Plate IV

Fig. 1. External view of both valves of a stenomorph specimen of *Teredo navalis*. Actual size .94 mm.

Fig. 2. Internal view of both valves of a stenomorph specimen of *Teredo navalis*. Actual size .94 mm.

Fig. 3. External view of both valves of a normal specimen of *Teredo navalis*. Actual size 1.3 mm.

Fig. 4. External view of left valve of a stenomorph specimen of *Bankia gouldi*. Actual size 2.7 mm.

Fig. 5. Pallets of stenomorph *Teredo navalis* shown in fig. 1. Actual size .95 mm.

EXPLANATION OF PLATE

Plate V

Fig. 1. Wood containing many stenomorphic specimens of *Teredo navalis* from Warren, R. I.

Fig. 2. Wood showing attack of normal *Teredo navalis* from Fall River, Mass.

Fig. 3. Tube of a *Bankia gouldi* in a shingle block.

FIG. 1

FIG. 3

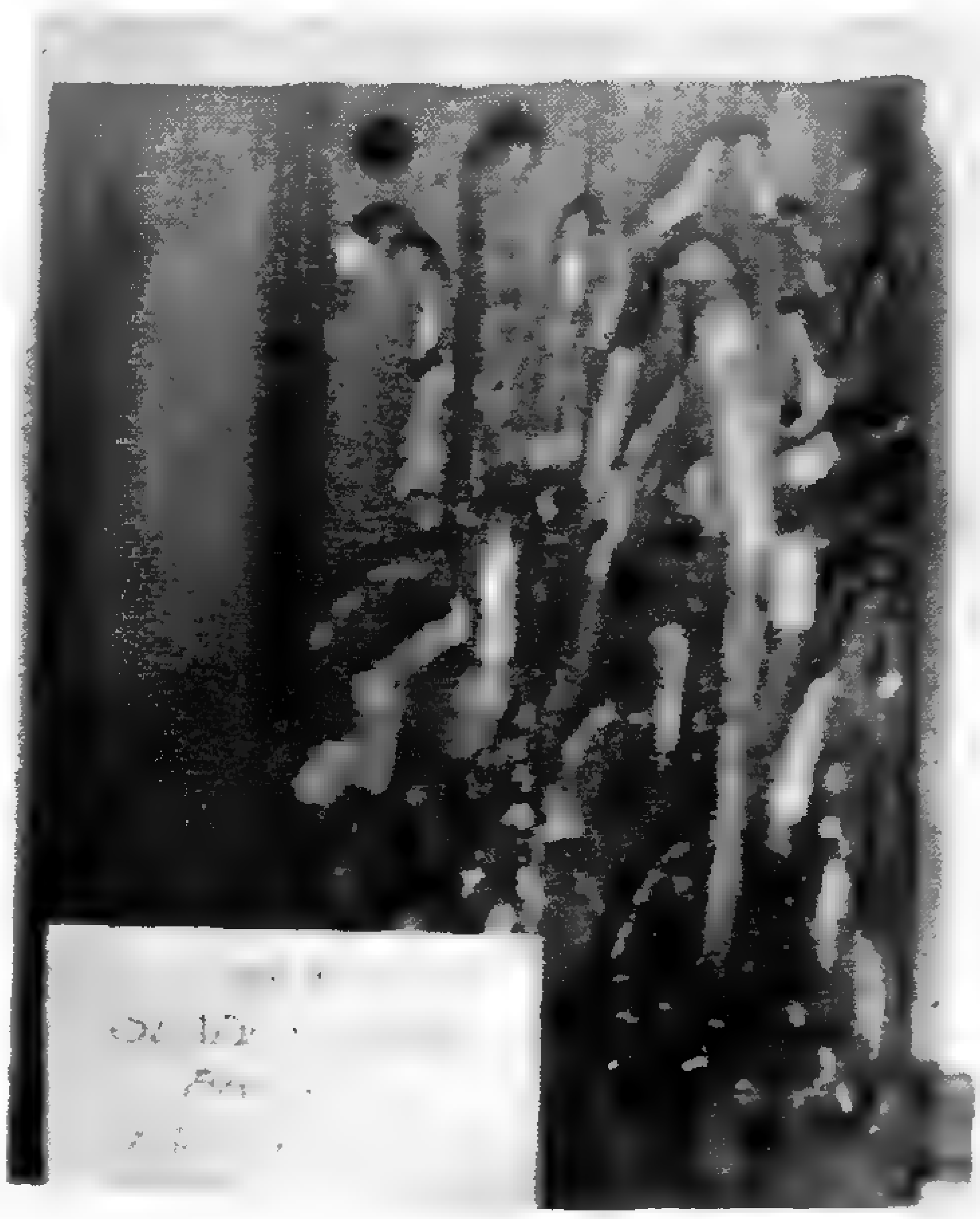

FIG. 2

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SUPPLEMENT TO THE CATALOGUE OF ARKANSAS PLANTS

J. T. BUCHHOLZ and E. J. PALMER

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SUPPLEMENT TO THE CATALOGUE OF ARKANSAS PLANTS.*

J. T. Buchholz and E. J. Palmer.

More than thirty-six years have elapsed since the publication of a Catalogue of the Flora of Arkansas. We are presenting here the first supplement to the List of Arkansas Plants by Branner and Coville (35). Many plant names have been changed since this publication, but we are not attempting to include names in this list where mere changes in synonymy are involved, except in a few instances where these changes are such as would not be included with the synonymy given in current botanical manuals. Our supplementary list of plants presented here consists almost exclusively of additions to the former catalogue and includes also the species reported by various other botanists, both in publications appearing since 1890, and from reports rendered privately to the Department of Botany of the University of Arkansas within the last six years.

One or more collection numbers are given where possible. However, collections made by J. T. Buchholz were usually not numbered, and when thus marked, all numbers used by this observer are below 1000. Nearly all of these specimens are in the Herbarium of the University of Arkansas. Collection numbers of Arkansas plants by E. J. Palmer are those given with numbers above 4000, unless otherwise stated, and duplicate specimens of many of these plants are in the Herbarium at Fayetteville. Most of the early collections by Palmer

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are to be found in the Herbarium of the Missouri Botanical Garden, while a complete set of collections of all ligneous species with Palmer numbers is to be found in the Herbarium of the Arnold Arboretum.

The flora of Arkansas has been largely neglected by botanists during the last thirty-six years. Those who have collected within the State have usually been rewarded by the discovery of many new and rare species of plants. It is safe to predict that as this flora becomes better known very many more additions will be made, and with a more careful and critical study of the material many new species and varieties will be added.

The Catalogue of Plants by Branner and Coville (34) included 1610 ferns and seed plants. A small reduction must be made from this list for plants erroneously reported or those now represented under new names among our 534 additions. However, it may safely be estimated that the known ferns and seed plants of Arkansas now comprise about 2100 species.

The earliest naturalists to visit and report on the vegetation of the area included in this state, of which there are available records, were Bradbury (1) in 1809-11, Schoolcraft (2) in 1818-1819 and Nuttall in 1819. All of these early explorers gave valuable and interesting accounts of the geography and vegetation, but the celebrated botanist Nuttall described the vegetation in greatest detail and published valuable contributions including the descriptions of many new species of plants (4, 5, 7). Nuttall's Journal of Travels Into Arkansa Territory (3) is considered a classic in the literature of travel, and this together with his Collection Towards a Flora of the Territory of Arkansas (7), are noteworthy contributions to the flora of the West. His Flora of Arkansas was never completed, but he mentioned many plants in his Journal of Travels, and described others in his Flora and other contributions (4, 5). The works of Bradbury, Schoolcraft and Nuttall constitute the earliest reliable records on the flora of Arkansas.

In 1834 Featherstonehaugh traveled through Missouri and Arkansas from the Missouri to the Red River. Though his report (6) was largely geological, he made frequent mention of many species of plants observed and the types of vegetation encountered.

In 1859 Professor Leo Lesquereux made a study of the fossil and recent flora of the state for the Second State Geological Survey, and gave a description of the botanical features of the northern and northwestern counties and a catalogue of Arkansas plants (8), including those observed and reported by Nuttall. As Lesquereux did his work during October-December and covered very extensive territory, he probably did not assemble an herbarium.

To this catalogue Butler added a list (9) of over a hundred species in 1877. Prof. F. L. Harvey published many short articles and notes in the Botanical Gazette (10-15, and 17-29) between 1880 and 1885, including a more comprehensive treatise on the Ferns of Arkansas (17-18) and one on the arboreal flora (32). Harvey began to assemble an herbarium. A large portion of his collection is still preserved at the University of Arkansas, and many of his duplicates were exchanged with other herbaria.

Professor R. Ellsworth Call, who was engaged in a study of the geology of Crowley's Ridge, prepared two special reports on the native forest trees of this region (33, 37). He probably did not assemble any collections. J. Francis Williams made a special study of the timber of the Magnet Cove region (38) and reported a definite relation between the vegetation and the underlying igneous rocks, confirming a feature previously mentioned by Featherstonehaugh, but apparently not observed by Harvey (21).

In the Annual Report of the Arkansas Geological Survey for 1888 Branner and Coville (35) published the most recent comprehensive catalogue of Arkansas plants, a publication which appeared in 1891. This also included a discussion of the general botanical features of the state (35). Coville made some collections which are on deposit in the U. S. National Museum, but the bulk of the work done for the plant list seems to have been based on field notes. The Harvey collection at Fayetteville was worked over by Professor Simonds in preparing the Branner and Coville catalogue.

An extensive collection made by Mr. E. N. Plank, who lived at Decatur, Arkansas, for many years, was acquired by the New York Botanical Garden. The Plank collection contained many Arkansas plants, but he seems not to have published a list of these except in a single brief paper: "Concerning the Plants of Southwestern Arkansas" (41). The material collected by Plank and included in this report has been consulted at the herbarium of the New York Botanical Garden.

In an ecological study, Dr. S. M. Coulter, (43) recorded a number of swamp species new to Arkansas. Similarly Dr. Roland M. Harper (47-49) has made records of a number of species characteristic of our prairie and the coastal plain region of southeastern Arkansas, containing names new to the state. More recently Dr. Harper and Rev. H. E. Wheeler sent us specimens representing unreported species, as credited to them. Others contributing data, specimens, or assistance in finding favorable collecting stations are: Mr. Ralph Shreve of Farmington, Prof. D. Demaree of Hendrix College, Conway; Mr. W. W. Ashe of the Forest Service; staff members of the Agricultural Experiment Station, Fayetteville; some of the county agricultural agents and a number of former students of the University of Arkansas. These miscellaneous unpublished records are included here with the name of the observer. From these, from some of our own publications, and for the most part from our other unpublished records, this list of additions to the catalogue of Arkansas plants has been prepared. A list of publications pertaining entirely or in part to the flora of Arkansas is given below. This is represented by a complete collection of these publications, nearly all bound in eight volumes deposited in the University of Arkansas Library.

PTERIDOPHYTA.

Polypodiaceae:

Polypodium virginianum L. (formerly reported as *P. vulgare* L.) Fayetteville, Washington Co.; Jasper, Newton Co.; Magazine Mountain, Logan Co., probably the southwestern limit of the species.

Pteridium aquilinum var. *pseudocaudatum* Clute. Savoy, Washington Co.

Pellaea glabella Mett. Bentonville (near Bella Vista), Benton Co.

Asplenium platyneuron forma *serratum* (E. S. Miller) R. Hoffman. On chert and limestone rocks, with the species.

Polystichum achrostichoides forma *incisum* (Gray) Gilbert. With typical form, chert hills, Northwest Arkansas.

Dryopteris spinulosa (Muell.) Kuntze. On north slope, Magazine Mountain, Logan Co. (D. M. Moore).

Woodsia scopulina D. C. Eaton. On sandstone ledges, north side of Magazine Mountain, Logan Co., near the summit.

Dennstaedtia punctilobula (Mich.) Moore. On partially shaded damp sandstone cliffs, north side of Magazine Mountain, Logan Co. 24142.

Ophioglossaceae:

Ophioglossum Engelmanni Prantl. 5376 Fulton, Hempstead Co., clay barrens; also in glades and rocky barrens of the Ozark region.

Botrychium obliquum var. *tenuifolium* (Underw.) Gilbert. 24008 McNab, Hempstead Co.

Botrychium obliquum var. *dissectum* (Spreng.) Clute. Farmington, Washington Co. Low woods, rare, occurs with the species.

Equisetaceae:

Equisetum hyemale var. *intermedium* Eat. fide J. H. Schaffner. On calcareous deposits near spring, Jasper, Newton Co.

Equisetum praealtum Raf. (*E. robustum* (A. Br.) A. A. Eaton.) Includes the plants formerly referred to *E. hyemale*. Along sandy river banks.

Isoetaceae:

Isoetes Butleri Engelm. Little Rock, on "Pulaskite," Fourche Mountain; Eureka Springs, Carroll Co. (Bush).

Isoetes melanopoda J. Gay. In springy ground, top of Magazine Mountain, Logan Co.; 24921 Hot Springs, Garland Co.; Farmington, Washington Co.

MONOCOTYLEDONAE.

Sparganiaceae:

Sparganium americanum Nutt. Prairie View, Washington Co.; 10598 Washington, Hempstead Co.; 8358 Ashdown, Little River Co.

Alismaceae:

Sagittaria longirostra (Micheli) J. G. Sm. Fayetteville, Washington Co.; 10599 Washington, Hempstead Co.

Sagittaria papillosa Buch. 25043 Hazen, Prairie Co.

Graminae:

Erianthus strictus Baldw. Fulton, Hempstead Co. (4386 Greenman).

Paspalum distichum L. Fulton, Hempstead Co. (4387 Greenman).

Paspalum circulare Nash. 6363 Beaver, Carroll Co.

Paspalum elatum L. C. Rich. Corning, Clay Co.

Paspalum laeviglume Scribn. 26210 Cotter, Baxter Co.

Paspalum Muhlenbergii Nash. 6093 Corning, Clay Co.; 6370 Beaver, Carroll Co.; 8175 Fayetteville, Washington Co.

Panicum Boscii Poir. 8426 Benton, Saline Co.

Panicum commutatum Schultes. 25015 Little Rock; 24880 Hot Springs, Garland Co.

Panicum Helleri Nash. Eureka Springs, Carroll Co.

Panicum huachucae Ashe. 24827 Magazine Mountain, Logan Co.

Panicum linearifolium Scribn. 5611 Eureka Springs, Carroll Co.; 25178 Shirley, Van Buren Co.

Panicum lucidum Ashe. 25169 Shirley, Van Buren Co.

Panicum mutabile Scribn. & Smith. 24872 Hot Springs, Garland Co.

Panicum polyanthes Schultes. 25053 Hazen, Prairie Co.

Panicum Scribnerianum Nash. 5558 Eureka Springs, Carroll Co.

Panicum tennesseense Ashe. Westfork, Washington Co.

Panicum Werneri Scribn. 5610 Eureka Springs, Carroll Co.; 25024 Hazen, Prairie Co.

Echinochloa colona (L.) Link. 26727 McNab, Hempstead Co.

Digitaria Ischaemum Schreb. (*Digitaria humifusa* Rydb.) 4564 Eureka Springs, Carroll Co.

Digitaria villosa (Walt.) Ell. Arkadelphia, Clark Co. (fide H. R. Rosen).

Axonopus furcatus (Fluegge) Hitchc. 10594 Washington, Hempstead Co.

Setaria viridis (L.) Beauv.

Holcus halepensis L. (*Sorgum halepense* Pers.) Naturalized in waste places and widely distributed.

Sporobolus canovirens Nash. 6908 Harrison, Boone Co.

Sporobolus cryptandrus (Torr.) Gray. 6055 Corning, Clay Co.

Sporobolus pilosus Vasey. 4374 Eureka Springs, Carroll Co.

Sporobolus vaginaeflorus Torr. Fide Standley and Hitchcock, from specimens by County Agr. Agent.

Agrostis Elliottiana Schultes. Central Arkansas, from District Agr. Agent.

Eragrostis glomerata (Walt.) Dewey. El Dorado, Union Co.

Bromus secalinus L. Warren, Bradley Co.

Bromus tectorum L. Fayetteville, Washington Co.

Sphenopholis pallens (Spreng.) Scribn. 25168 Shirley, Van Buren Co.

Glyceria septentrionalis Hitchc. 25046 Hazen, Prairie Co.

Elymus arkansanus Scribn. & Ball. North Arkansas, District Agr. Agent.

Elymus australis Scribn. & Ball. Fayetteville, Washington Co.; 8126 Benton, Saline Co.

Elymus glabriflorus (Vasey) Scribn. & Ball. Lake Village, Chicot Co.

Cyperaceae:

Cyperus compressus L. 14641 McNab, Hempstead Co.

Cyperus cylindricus (Ell.) Britton. Fulton, Hempstead Co. (fide J. M. Greenman).

Cyperus ferax Rich. 26747 Fulton, Hempstead Co.

Cyperus Houghtonii Torr. Fayetteville, Washington Co.

Cyperus hystricinus Fernald. 14657 McNab, Hempstead Co.

Cyperus lancastriensis Porter. 8124 Benton, Saline Co.

Cyperus pseudovegetus Steud. 6061, 8026 Fulton, Hempstead Co.

Cyperus rivularis Kunth. 4565 Eureka Springs, Carroll Co.

Cyperus speciosus var. *ferruginescens* (Boeckl.) Britton. Fayetteville, Washington Co.

Eleocharis Torreyana Boeckl. Lonoke Co., woods of second bottoms.

Fimbristylis Baldwiniana Torr. Stuttgart, Arkansas Co. (H. R. Rosen). A troublesome weed of rice fields.

Fimbristylis castanea var. *puberula* (Michx.) Britton. 5531 Eureka Springs, Carroll Co.; Hazen, Prairie Co., and Stuttgart, Arkansas Co., where a troublesome weed in rice fields.

Fuirena hispida Ell. 8099 Gifford, Hot Springs Co.

Fuirena simplex Vahl. 6002 Cotter, Baxter Co.; 8370 Ashdown, Little River Co.

Scirpus debilis Pursh. Lonoke Co., Portland clays (rice land soil).

Rynchospora corniculata (Lam.) Gray. 8070 Arkadelphia, Clark Co.; 10520 Doddridge, Miller Co.

Rynchospora cymosa Ell. South Arkansas, District Agr. Agent.

Rynchospora gracilenta Gray. 8095 Gifford, Hot Springs Co.

Rynchospora macrostachya Torr. 6071 Corning, Clay Co.

Rynchospora Plankii Britton. Benton Co. (type locality); Washington Co.

Carex arkansana Bailey. Arkansas River Valley.

Carex Bicknellii Britton. 25060 Hazen, Prairie Co.

Carex cherokeensis Schwein. 27104a Conway, Faulkner Co.; Pulaski Co., Roland M. Harper.

Carex communis, Bailey. 26930 Magazine Mountain Logan Co.; 27098 Jasper, Newton Co.

Carex crus-corvi Schuttlw. Corning, Clay Co.

Carex debilis var. *Rudgei* Bailey. 27142 Conway, Faulkner Co.; 24938 Lonsdale, Garland Co.

Carex festucacea var. *brevior* (Dewey) Fernald. 27107a Conway, Faulkner Co.

Carex glaucodea Tuckerm. 25069 Hazen, Prairie Co.; 24874 Hot Springs, Garland Co.

Carex gynandra (Schwein.) Boott. 24927a Lonsdale, Garland Co.

Carex hormathodes var. *Richii* Fernald. 27007 Tontitown, Washington Co.

Carex intumescens Rudge. 24990 Fulton, Hempstead Co.

Carex Jamesii Schwein. Fayetteville, Washington Co.; 5581 Beaver, Carroll Co.

Carex Joorii Bailey. 24004 Fulton, Hempstead Co.

Carex lanuginosa Michx. 24747 Fayetteville, Washington Co.

Carex laxiflora var. *gracillima* Boott. 24746 Fayetteville, Washington Co.; 24452 Hot Springs, Garland Co.

Carex laxiflora var. *latifolia* Boott. 6038 Rush, Marion Co.

Carex leptalea Wahlenb. 27132 Lofton, Hot Springs Co.

Carex louisianica Bailey. 27106 Conway, Faulkner Co.; Lonoke Co., heavy clay soil in woods.

Carex lupulina var. *pedunculata* Bailey. 6047 Corning, Clay Co.

Carex Meadii Dewey. 5533 Eureka Springs, Carroll Co.

Carex Muhlenbergii var. *enervis* Boott. 5552 Eureka Springs, Carroll Co.; 24815 Magazine Mountain, Logan Co.

Carex oligocarpa Schkuhr. 27036 Goshen, Washington Co.; 24849 Magazine Mountain, Logan Co.

Carex platyphylla Carey. 26929 Magazine Mountain, Logan Co.

Carex Sartwellii Dewey. Lonoke Co.

Carex scirpoidea Michx. 24928 Lonsdale, Garland Co.

Carex echinata var. *angustata* (Carey) Bailey. 27105a Conway, Faulkner Co.

Carex stricta var. *decora* Bailey. 24745 Fayetteville, Washington Co.

Carex tetanica Schkuhr. 27041 Eureka Springs, Garland Co.

Carex torta Boott. 26898 Lawrence, Garland Co.

Commelinaceae:

Tradescantia brevicaulis Raf. Fayetteville, Washington Co. On sandstone, cap rock of high hills.

Tradescantia hirsuticaulis Small. Hot Springs, Garland Co. (Roland M. Harper). Dry woods near summit of West Mountain.

Tradescantia occidentalis (Britton) Smyth. 25067 Hazen, Prairie Co.; Lonoke, Lonoke Co.

Tradescantia reflexa Raf. England, Lonoke Co.

Commelina communis L. (C. nudiflora Gray). Texarkana, Miller Co.

Juncaceae:

Juncus aristulatus Michx. Hazen, Prairie Co. (Roland M. Harper).

Juncus brachycarpus Engelm. 25065 Hazen. Prairie Co.; Jonesboro, Craighead Co., and S. E. Arkansas. (Roland M. Harper.)

Juncus Dudleyi Wiegand. 5995 Cotter, Marion Co.

Luzula campestris var. *bulbosa* A. Wood (*Juncoides bulbosum* (Wood) Small). Most of our plants, probably all, belong to this variety or species. N. W. and central Arkansas.

Liliaceae:

Allium stellatum Ker. West Fork, Washington Co.; 4370 Eureka Springs; Sulphur Springs, Benton Co.

Lilium superbum L. Wet meadows, Fayetteville, Washington Co. (C. Chandler).

Stenanthium robustum Watson. Fayetteville, Washington Co.; 8205 Brentwood, Washington Co.

Toxicoscordion Nuttallii (Gray) Rydb. 24929 Lonsdale, Garland Co.; Magazine Mountain, Logan Co.; Rudy, Crawford Co.

Trillium pusillum. Michx. Valley of Osage Creek and Monte Ne region, Washington and Benton Co.; War Eagle Creek Valley, Madison Co. Occurs in cherty soil in woods (rare).

Trillium Underwoodii. Small. Near Batesville, Independence Co. ("Cherty slope near Polk Bayou"—Roland M. Harper).

Smilax hispida Mühl. 10558 Cotter, Marion Co.; 22207 Van Buren, Crawford Co.

Dioscoreaceae:

Dioscorea villosa var. *glabra.* Lloyd. 5945 Cotter, Marion Co.

Amaryllidaceae:

Hypoxis hirsuta (L.) Coville (*H. erecta* L.) 25027 Hazen, Prairie Co. Also frequent in Ozark region.

Iridaceae:

Iris cristata Ait. (Formerly reported as *I. verna* L.) Cherty hills in woods north and west of Fayetteville, Washington and Benton Co.; similar situations Madison and Carroll Cos.; top of Magazine Mountain, Logan Co. A form with white flowers has been collected at Farmington and Hot Springs.

Iris foliosa. Mackenzie & Bush. Prairie Grove and Farmington, Washington Co. Rare and local (Ralph Shreve).

Sisyrinchium albidum Raf. 25061 Hazen, Prairie Co.; Fayetteville, Washington Co.

Sisyrinchium furcatum Bicknell. 25050 Hazen, Prairie Co.

Sisyrinchium graminoides Bicknell. Fayetteville, Washington Co. Common throughout the state.

Orchidaceae:

Cypripedium pubescens Willd. A specimen sent from Red Star, Newton Co., compared with material at the Herbarium of the New York Botanical Garden was found to be typical for leaf and size; 24993 McNab, Hempstead Co.

Spiranthes ovalis Lindl. (*Ibidium ovale* (Lindl.) House). Conway, Faulkner Co.

Spiranthes vernalis Engelm. & Gray. Fayetteville, Washington Co.; 8146 Ozark, Franklin Co.

Corrallorrhiza Wisteriana Conrad. Fayetteville, Washington Co.; Fulton, Hempstead Co.

Pogonia verticillata (Willd.) Nutt. 26894 Lawrence, Garland Co.

DICOTYLEDONAE.

Salicaceae:

Populus balsamifera var. *virginiana* (Henry) Sarg. Common Cottonwood. Formerly *Populus deltoides* Marsh. (*P. monilifera* Ait.) Distribution general along streams.

Salix cordata Muhl. Johnston, Washington Co.

Salix nigra var. *altissima* Sarg. Tall black willow. 5394 Fulton, Hempstead Co.

Salix longifolia Muehl. Sand Bar Willow. 24978, McNab, Hempstead Co.; 25013, Little Rock, Pulaski Co.; 25085, Helena, Phillips Co.

Salix longipes var. *Wardii* (Bebb) Schneider. Ward's willow. Fayetteville, Washington Co.; Eureka Springs and Beaver, Carroll Co.; Cotter, Marion Co.

Salix longipes var. *Wardii* x *nigra*. 20500 Eureka Springs, Carroll Co.

Leitneriaceae:

Leitneria floridana Chapm. Cork tree. 4792 Moark, 6074 Corning, Clay Co.; St. Francis River swamps (S. M. Coulter).

Juglandaceae:

Carya alba var. *ficoides* Sarg. 20990 and 22198 Van Buren, Crawford Co.

Carya alba var. *ovoidea* Sarg. 29441 McNab, Hempstead Co.

Carya alba var. *subcoriacea* Sarg. The common form in Southern and Eastern Arkansas.

Carya Buckleyi var. *arkansana* Sarg. 20991 Van Buren, Crawford Co. (type locality); 20638 Fulton, Hempstead Co.; 10524 Doddridge, Miller Co. Common throughout the state.

forma *pachylemma* Sarg. Fulton, Hempstead Co. (type locality).

Carya cordiformis var. *latifolia* Sarg. 8219 Fayetteville, Washington Co.; 20671 Cotter, Marion Co.

Carya leiodermis Sarg. 8953 Fulton, Hempstead Co.; 26653 Helena, Phillips Co.; 26491 Mt. Nebo, Yell Co.; 26424 Magazine Mountain, Logan Co.

Carya ovalis var. *obovalis* Sarg. Northern Arkansas.

Carya ovalis var. *obcordata* Sarg. 22267 Fulton, Hempstead Co.

Carya texana DC. Bitter Pecan. Van Buren, Crawford Co., bottom lands of Arkansas River (G. M. Brown).

X *Carya Brownii* Sarg. Van Buren, Crawford Co., bottom lands of Arkansas River. A hybrid between Carya cordiformis and C. pecan.

X *Carya Brownii* var. *varians* Sarg. Van Buren, Crawford Co. (G. M. Brown).

Carya alba x *Buckleyi arkansana.* 20989, 22210 Van Buren, Crawford Co.

Betulaceae:

Corylus rostrata Ait. Beaked Hazelnut. 26692 Jonesboro, Craighead Co.

Fagaceae:

Castanea alnifolia var. *floridana* Sarg. 413 McNab, Hempstead Co.; 8440 Benton, Saline Co.; 26536 Hardinville, Faulkner Co. (*C. Margaretta* Ashe).

Castanea ozarkensis Ashe. Ozark Chinquapin. (*C. arkansana* Ashe). War Eagle, Madison Co. (type locality); Benton, Washington, Carroll and other northern and western counties. (Formerly referred to *C. pumila.*)

Fagus grandifolia var. *caroliniana* Fern. & Rehd. Beech. 8076 Gum Springs, Clark Co.; Pettigrew, Madison Co., and along Mulberry Creek in Madison and Franklin Cos. The forma *mollis* Fern. & Rehd. has also been found at Helena, Phillips Co.

Quercus arkansana Sarg. Arkansas Oak. 5383, 7188, 8043, etc. McNab, Hempstead Co. Locally common in sand hills northwest of Fulton.

Quercus borealis Michx. Coll. by W. W. Ashe in Ozark National Forest near Lurton, Newton Co.

Quercus borealis var. *maxima* Ashe. Northern Red Oak. (Formerly erroneously called *Q. rubra.*) 6360 Beaver, 20510 Eureka Springs, Carroll Co.; 14300 Cotter, Marion Co.; Conway, Faulkner Co.; Fayetteville and Savoy, Washington Co., and in all of the northern, western and central counties.

Quercus coccinea Wang. Scarlet Oak. Jonesboro, Craighead Co.; reported by R. M. Harper from near Forrest City, St. Francis Co.

Quercus Durandii Buckley. Durand's Oak. 5378, 6818, etc. Fulton, 8050 McNab, Hempstead Co.

Quercus nigra var. *heterophylla* (Ait.) Ashe. 23995 Texarkana, Miller Co.; 24011 McNab, Hempstead Co.; 24312 Shirley, Van Buren Co.

Quercus palustris Muench. Pin Oak. 6069 Corning, Clay Co.; 21000 Van Buren, Crawford Co.; Conway, Faulkner Co.; Russellville, Pope Co.; Clarendon, Monroe Co. Reported by Harvey but omitted by Branner & Coville.

Quercus Phellos L. Willow Oak. Conway, Faulkner Co.; Pine Bluff, Jefferson Co.; Alma, Crawford Co.; Clarksville, Johnson Co. Reported by Harvey but omitted by Branner & Coville.

Quercus prinoides Willd. Shin Oak, Prairie Oak. Benton Co., margins of prairies (F. L. Harvey).

Quercus obtusa Ashe. Water Oak. Southern Arkansas. *Q. rhombica* Sarg.)

Quercus rubra L. Southern Red Oak. (Formerly *Quercus triloba* Michx., *Q. digitata* Sudw., *Q. falcata* Michx.) Common throughout except in parts of Ozark region.

Quercus rubra var. *leucophylla* Ashe. Little Rock, Pulaski Co.; Fulton, Hempstead Co.; Stuttgart, Arkansas Co.; Conway, Faulkner Co.

Quercus rubra var. *pagodaefolia* (Ell.) Ashe. Coastal Plains, S. E. Arkansas (fide Roland M. Harper).

Quercus Shumardii Buckley, Spotted Oak. (Formerly reported as *Quercus texana.*) Fulton, 20635 McNab, Hempstead Co.; Dermott, Chicot Co.; Savoy, Washington Co.; 6009 Cotter, Marion Co.

Quercus Shumardii var. *Schneckii* (Britton) Sarg. Spotted Oak. 8182 Fayetteville, Washington Co.; Benton Co.; Madison Co.; 4453 Eureka Springs, Carroll Co.; 8949 Fulton, Hempstead Co.

Quercus stellata Wang. Post Oak. (*Quercus minor* Sarg.) General distribution. Listed by Harvey but omitted by Branner and Coville.

Quercus stellata var. *araniosa* Sarg. Sand Post Oak. 22454, 8985, Texarkana, Miller Co.; 8439 Benton, Saline Co.

Quercus stellata var. *Margaretta* Ashe. Southern Arkansas.

Quercus velutina var. *missouriensis* Sarg. Benton Co.; Washington Co.; Austin, Lonoke Co.; Conway, Faulkner Co.

Hybrid Oaks:

X *Quercus Bushii* Sarg. (*Q. marilandica* x *Q. velutina.*) 20509 Eureka Springs, Carroll Co.; Fayetteville, Washington Co. (Mock St. and also on Lindell Ave.)

X *Quercus Rudkinii* Britton. (*Q. marilandica* x *Q. Phellos.*) 10504, 23999, etc. Fulton, Hempstead Co.

X *Quercus Schochiana* Dieck. (*Q. palustris* x *Q. Phellos.*) 27096 Dover, Conway Co.; Faulkner Co. (D. Demaree).

X *Quercus subfalcata* Trel. (*Q. Phellos* x *Q. rubra.*) 22466, 24013, etc. Fulton and McNab, Hempstead Co.; Cove Creek, Faulkner Co. (D. Demaree).

Quercus Durandii x *stellata.* 12659, 20715, etc. McNab, Hempstead Co.

Quercus nigra x *Shumardii.* 22301 McNab, Hempstead Co.

Quercus nigra x *rubra.* 23139, 24876, etc. Hot Springs, Garland Co.

Ulmaceae:

Ulmus serotina Sarg. 6944, Jasper, Newton Co.; 21013 Van Buren, Crawford Co.; 26603 Magnet Cove, Hot Springs Co.; 22277 McNab, Hempstead Co.

Celtis laevigata var. *texana* Sarg. Southern Hackberry. 412 McNab, Hempstead Co.; 20491 Eureka Springs, Carroll Co. Common throughout the state.

Celtis occidentalis var. *canina* (Raf.) Sarg. Fayetteville, Goshen, Washington Co.; 14329 Cotter, Marion Co.

Celtis occidentalis var. *crassifolia.* (Lam.) Gray. Rough leaved Hackberry. 20672 Cotter, Marion Co.; 22208, 21012 Van Buren, Crawford Co.

Celtis pumila var. *georgiana* (Small) Sarg. Savoy, West Fork, Washington Co.

Moraceae:

Broussonetia papyrifera (L.) Vent. (*Papyrius papyrifera* (L). Kuntze). Cultivated, occasionally escaped. Paper Mulberry.

Aristolochiaceae:

Asarum reflexum. Bicknell. Johnson, Goshen, Kessler Mountain, West Fork, Washington Co. Frequent in Ozark region.

Aristolochia reticulata. Nutt. 8058 McNab, Hempstead Co.; 8384 Ashdown, Little River Co. Reported in Nuttall's Arkansas Flora but omitted from all subsequent lists.

Polygonaceae:

Eriogonum longifolium Nutt. 14319 Cotter, Marion Co. In sandy soil.

Eriogonum hirsutum Nutt. North Arkansas and Missouri border region, confined to calcareous rocks.

Polygonum densiflorum Meisn. (*Persicaria portoricensis* Small.) St. Francis River, Mississippi Co. (S. M. Coulter).

Chenopodiaceae:

Chenopodium Botrys L. 14304 Cotter, Marion Co.

Amaranthaceae:

Froelichia gracilis Moq. Fayetteville, 8215 Brentwood, Washington Co.

Nyctaginaceae:

Boerhaavia erecita L. 8065 Arkadelphia, Clark Co.; 24257 Hot Springs, Garland Co.

Caryophyllaceae:

Cerastium brachypodum (Engelm.) Robinson. Short stalked Chickweed. Fayetteville, Washington Co. Waste fields.

Cerastium semidecandrum L. Fayetteville, Washington Co.

Stellaria media (L.) Cyrill. Common Chickweed. Waste places over entire state, sometimes flowering during all months of winter.

Saponaria Vaccaria L. Cow herb. Conway, Faulkner Co., near tunnel (H. E. Wheeler).

Silene nivea (Nutt.) Otth. Fayetteville, Washington Co., escaped from cultivation.

Portulacaceae:

Talinum calycinum Engelm. 4563 Eureka Springs, Carroll Co.; 26215 Cotter, Baxter Co.

Talinum parviflorum Nutt. Thin soil above sandstone cap rock of waterfall near Winslow, Washington Co.; Fourche Mountain, Little Rock, on "Pulaskite" rocks.

Nymphaeaceae:

Cabomba caroliniana Gray. Near Blytheville, Mississippi Co.; St. Francis River swamps (S. M. Coulter).

Ranunculaceae:

Anemone caroliniana Walt. Fayetteville, Washington Co.; Conway, Faulkner Co.

Anemone decapetala Ard. Along sandstone cliffs, south slopes, near base of Magazine Mountain, Logan Co.

Delphinium Nortonianum Mackenzie & Bush. Fayetteville, Washington Co.

Delphinium Treleasei Bush. 27038 Eureka Springs, Carroll Co.

Delphinium Penardii Huth. 5585 Beaver, Carroll Co. Frequent in barrens and on prairies of Ozark region.

Ranunculus hispidus Michx. 5597 Eureka Springs, Carroll Co.

Thalictrum texanum (Gray) Small. 7151 Fulton, Hempstead Co.

Clematis versicolor Small. (*Viorna versicolor* Small.) 6352 Beaver, Carroll Co.; 8226 Westfork, Fayetteville, Washington Co.

Clematis reticulata Walt. (*Viorna reticulata* Small.) 10508 Columbus, Hempstead Co.

Clematis paniculata Thunb. 20498 Eureka Springs, Carroll Co. Introduced along rocky creek.

Anonaceae:

Asimina parviflora (Michx.) Dunal. Crowley's Ridge north of Helena, Phillips Co. (fide Roland M. Harper.)

Menispermaceae:

Cocculus carolinus (L.) DC. (*Epibaterium carolinum* Britton). 6005 Cotter, Marion Co.; 22193 Van Buren, Crawford Co.; Fayetteville, Washington Co. Common throughout the state.

Calycocarpum Lyoni (Pursh) Nutt. 25153 Helena, Phillips Co.; 26541 Cove Creek, Faulkner Co.; 24290 Shirley, Van Buren Co.

Fumariaceae:

Corydalis campestris (Britton) new comb. (*Capnoides campestre* Britton). Benton Co. (Type locality).

Cruciferae:

Coronopus didymus (L.) J. E. Sm. 24989 Fulton, Hempstead Co.; Conway, Faulkner Co. A troublesome pasture weed.

Sisymbrium altissimum L. (*Norta altissima* Britton). 8158 Ozark, Franklin Co.; Washington Co.

Erysimum inconspicuum (Wats.) MacM. Northwest Arkansas (E. N. Plank).

Camelina sativa (L.) Crantz. Gold of Pleasure. Fayetteville, Washington Co. Naturalized from Europe.

Dentaria laciniata Muhl. 24855 Magazine Mountain, Logan Co.

Cardamine pennsylvanica Muhl. 24458 Hot Springs, Garland Co.; Fayetteville, Washington Co.

Cardamine parviflora L. 7176 Fulton, Hempstead Co.; 24451 Hot Springs, Garland Co.; Conway, Faulkner Co.; Fayetteville, Washington Co.

Droseraceae:

Drosera annua E. L. Reed. Conway, Faulkner Co., Campus of State Teachers College.

Saxifragaceae:

Saxifraga texana Buckl. (*Micranthes texana* Small). Conway, Faulkner Co.; Fayetteville, Washington Co.

Heuchera arkansana Rydb. (May be the *H. villosa* of Harvey.) On cliffs, Northwest Arkansas.

Heuchera hirsuticaulis (Wheelock) Rydb. Shaded north slopes, on Boone chert hills, Washington Co.

Heuchera macrorhiza Small. Fayetteville, Washington Co.

Heuchera parviflora Bartl. Springdale, Washington Co.; Shirley, Van Buren Co. On moist cliffs. Flowers in October.

Philadelphus pubescens Schrad. Cove Creek, Faulkner Co.; 6934 Jasper, Newton Co.; 6033 Rush, Marion Co.; Shirley, Van Buren Co.; Magazine Mountain Logan Co.

Hydrangea cinerea Small. 6959 Heber Springs, Cleburne Co.; 25160 Helena, Phillips Co.; 25205 Shirley, Van Buren Co.

Ribes Cynosbati L. Prickly Gooseberry. (*Grossularia Cynosbati* Mill.). 242 Rich Mountain, Polk Co.; Magazine Mountain, Logan Co.

Ribes missouriense Nutt. Gooseberry (*Grossularia missouriensis* Coville & Brit.) 5572 Beaver, Carroll Co.

Hamamelidaceae:

Hamamelis macrophylla Pursh. Witch-hazel. 249 Rich Mountain, Polk Co.; 8441 Benton, Saline Co.; 22296 McNab, Hempstead Co.

Hamamelis vernalis Sarg. Spring-blooming Witch-hazel. 6032 Rush Marion Co.; 12649, Mena, Polk Co.; Goshen, Washington Co. Common along rocky streams of Ozark region.

Hamamelis vernalis var. *tomentella* Sarg. 20494 Eureka Springs, Carroll Co.

Rosaceae:

Physocarpus intermedius (Rydb.) Schneider. Nine

Bark. (*Opulaster intermedius* Rydb.) 4385 Eureka Springs, Carroll Co.; 5573 Beaver, Carroll Co..; 5982 Cotter, Marion Co. Probably the *Neillia opulifolia* Benth. & Hook., observed by Lesquereux and by Harvey, belongs here.

Malus angustifolia (Ait.) Michx. Narrow-leaved Crabapple. 20719 Arkadelphia, Clark Co.

Malus iowensis var. *Palmeri* Rehd. 10581 Washington, Hempstead Co.

Crataegus. Crus-galli group:

Crataegus bellica Sarg. 5335, 5336 Fulton, Hempstead Co. (type locality).

Crataegus Bushii Sarg. 5344 Fulton, Hempstead Co. (type locality); 277 Rich Mountain, Polk County; 24531 High Point, Garland Co.

Crataegus erecta Sarg. 21017 Van Buren, Crawford County.

Crataegus Palmeri Sarg. Fayetteville, Washington Co.

Crataegus paradoxa Sarg. 20993 Van Buren, Crawford Co.

Crataegus pilifera Sarg. 5540 Eureka Springs, Carroll Co.; Van Buren, Crawford Co.

Crataegus subpilosa Sarg. Eureka Springs, Carroll Co. (type locality).

Crataegus triumphalis Sarg. 5371, 6825, Fulton, Hempstead Co. (type locality).

Crataegus palliata Sarg. Fulton, Hempstead Co. (type locality).

Crataegus villiflora Sarg. 5519, 5522. Eureka Springs, Carroll Co.; 20992, 22205 Van Buren, Crawford Co.

Crataegus. Punctatae group:

Crataegus fastosa Sarg. Fulton, Hempstead Co. (type locality).

Crataegus secta Sarg. 19028 Sulphur Springs, Benton Co.

Crataegus sordida var. *villosa* Sarg. 20709, 22266 McNab, Hempstead Co.

Crataegus sucida Sarg. 4387 Eureka Springs, Carroll Co.; 8179 Fayetteville, Washington Co.

Crataegus verruculosa Sarg. 24453 Hot Springs, Garland Co.

Crataegus. Virides group:

Crataegus amicalis Sarg. Fulton, Hempstead Co., (type locality).

Crataegus blanda Sarg. 20712 McNab, Hempstead Co.; 24496 Hot Springs, Garland Co.

Crataegus micrantha Sarg. Fulton, Hempstead Co. (type locality).

Crataegus velutina Sarg. Fulton, Hempstead Co. (type locality).

Crataegus viridis L. 4789 Moark, Clay Co.; 5345 Fulton, Hempstead Co.; 8134 Little Rock, Pulaski Co.; 8221 Greenland, Washington Co. The collections credited to Harvey as *C. arborescens* Ell. probably belong here, since this is the species occurring in the Fayetteville region.

Crataegus. Intricatae group:

Crataegus Harveyana Sarg. Eureka Springs, Carroll Co. (type locality); 26849 Hot Springs, Garland Co.

Crataegus leioclada Sarg. 4388, 5539, 5547, Eureka Springs, Carroll Co.

Crataegus neobushii Sarg. 5546 Eureka Springs, Carroll Co.

Crataegus villicarpa Sarg. 5525 Eureka Springs, Carroll Co.

Crataegus padifolia var. *incarnata* Sarg. 6026 Cotter, Marion Co.; 26611 Magnet Cove, Hot Springs Co.

Crataegus. Tenuifoliae (?) group:

Crataegus lacera Sarg. Fulton, Hempstead Co. (type locality).

Crataegus. Molles group:

Crataegus arkansana Sarg. Type (at Arnold Arboretum) from seed collected at Newport, Arkansas.

Crataegus brachyphylla Sarg. 432, 8975, 9393, 9392, 10607, 16333, 20711, McNab, Hempstead Co. (type locality).

Crataegus invisa Sarg. 5397, Fulton (type locality), 6879, 7193, 7196, McNab, Hempstead Co.

Crataegus induta Sarg. Fulton, Hempstead Co. (type locality).

Crataegus limaria Sarg. Fulton, Hempstead Co. (type locality).

Cartaegus transmississippiensis Sarg. 8419 Cotter, Marion Co. (type locality).

Crataegus. Dilatatae group:

Crataegus coccinoides Ashe. Farmington, Washington Co.

Crataegus. Uniflorae group:

Crataegus trianthophora Sarg. 6970 Heber Springs, Cleburne Co.; 26535 Cove Creek, Faulkner Co.; 26885 Lawrence, Garland Co.; 14322 Cotter, Marion Co.; Fulton, Hempstead Co. (B. F. Bush 5690); Baker Springs, Howard Co. (J. H. Kellogg).

Crataegus. Brachyacanthae group:

Crataegus brachyacantha Sarg. & Engelm. 315 Texarkana, Miller Co.; 8386 Ashdown, Little River Co.

Crataegus. Macracanthae group:

Crataegus carrollensis Sarg. Eureka Springs, Carroll Co. (type locality).

Crataegus hispidula Sarg. 5542 Eureka Springs, Carroll Co.

Crataegus mollicula Sarg. 6023 Rush, Marion Co.

Crataegus pudens Sarg. 20998, 22204 Van Buren, Crawford Co.

Crataegus tomentosa L. This species, reported by Branner & Coville, is found in Arkansas, but the variety *punctata* Gray (*C. punctata* Jacquin), reported also by them, probably does not occur here.

Crataegus aestivalis (Walt.) T. & G., *C. coccinea* L., *C. flexispina* (Moench) Sarg. and *C. subvillosa* Schrad., listed for Arkansas by Branner & Coville, very probably are not found here and should be dropped from the state plant list.

C. cordata Ait. (=*C. phaenopyrum* (L. f.) Medic.) and *C. crus-galli* L. reported by Harvey may occur in the northern counties.

Crataegus hybrids:

X *Crataegus notha* Sarg. A hybrid between *C. apiifolia* and *C. brachyphylla.* 8974, 20646, 20716 McNab, Hempstead Co.

Alchemilla arvensis Scop. Lady's Mantle. 23133 Hot Springs, Garland Co.

Potentilla recta L. Fayetteville, Washington Co.

Prunus mexicana Watson. Mt. Nebo, Yell Co.; Rich Mountain, Polk Co.; 7149 Fulton, 16329 McNab, Hempstead Co.; 20474 Eureka Springs, Carroll Co.; 20668 Cotter, Marion Co.

Prunus mexicana var. *fultonensis* Sarg. 12663 Fulton, Hempstead Co. (type locality).

Prunus mexicana var. *polyandra* Sarg. Fulton, Hempstead Co.

Prunus Munsoniana Wight & Hedrick. Fulton, Hempstead Co.

Prunus umbellata Ell. 8109 Gifford, Hot Springs Co.; 10597 Washington, Hempstead Co.

Prunus umbellata var. *tarda* (Sarg.) Wight. 10535 Arkadelphia, Clark Co.

Prunus angustifolia var. *varians* Wight. 7148 Fulton, Hempstead Co.

Rosa Eglanteria L. (*Rosa rubiginosa* L.) Escaped from cultivation, Fayetteville, Washington Co.

Rosa Lyonii Pursh. 24957 Hot Springs, Garland Co.; 24994 McNab, Hempstead Co.; 25055 Mesa, Prairie Co.; 25103 Helena, Phillips Co.

Rosa Palmeri Rydb. 8067 Ashdown, Little River Co.

Rosa setigera var. *tomentosa* T. & G. 22294 McNab, Hempstead Co.; 5978 Cotter, Marion Co.; 20507 Eureka Springs, Carroll Co.

Rosa subserrulata Rydb. 8159 Ozark, Franklin Co.; 10531 Ft. Lynn, Miller Co.; 6960 Heber Springs, Cleburne Co.; 8137 Little Rock, Pulaski Co.

Rosa texarkana Rydb. Type collected by Eggert, Texarkana, Miller Co.

Rubus occidentalis L. 5574 Beaver, Carroll Co. Common throughout Ozark region.

Rubus ostryaefolius Rydb. 16315 Texarkana, Miller Co.

Rubus Andrewsianus Blanchard. Fulton, Hempstead Co. The common high blackberry throughout the State.

Rubus rubrisetus Rydb. 327 Texarkana, Miller Co.; 20727 Gum Springs, Clark Co.

Leguminosae:

Amorpha croceolanata Watson. (*A. fruticosa* var. *croceolanata* Schneider). 948 Cove Creek, Faulkner Co.; 23051, 26863 Hot Springs, Garland Co.; 26918 Magnet Cove, Hot Springs Co.

Amorpha nitens Boynton. 23148, 26862 Hot Springs, Garland Co.; 26915 Magnet Cove, Hot Springs County.

Amorpha tennesseensis Shuttl. 20659 Cotter, Marion Co.; 24251 Hot Springs, Garland Co.; Van Buren, Crawford Co. (G. M. Brown).

Amorpha glabra Desf. 24187 Magazine Mountain, Logan Co.; Hot Springs, Garland Co.; Rich Mountain, Polk County.

Baptisia sulphurea Engelm. Little Rock, Pulaski Co. (H. E. Wheeler).

Cassia Medsgeri Shafer. Fayetteville and Westfork, Washington Co.; 6885 Eureka Springs, Carroll Co.; Cotter, Marion Co. Frequent in Ozark region and perhaps throughout the state.

Cladrastis lutea (Michx.) K. Koch. Kessler Mountain, near Farmington, Washington Co.; Magazine Mountain, Logan Co.; Shirley, Van Buren Co.; 8408 Cotter, Marion Co.

Lathyrus latifolius L. Perennial Pea. Fayetteville, Washington Co. Escaped from cultivation.

Lespedeza procumbens Michx. Fayetteville, Washington Co.; Eureka Springs, Carroll Co.

Medicago arabica Huds. Spotted Medick. Fayetteville, Washington Co. (R. H. Austin). Escaped from cultivation.

Medicago lupulina L. Black Medick. Fayetteville, Washington Co. Introduced.

Melilotus officinalis (L.) Lam. Yellow Sweet Clover. Washington Co., waste places, introduced and becoming common in many parts of the state.

Melilotus alba Desv. White Sweet Clover. Introduced and becoming abundant all over the state.

Desmodium paniculatum var. *pubens* T. & G. 4475 Eureka Springs, Carroll Co.

Petalostemum villosum Nutt. 5994 Cotter, Marion Co.

Phaseolus polystachyus (L.) B. S. P. Wild Kidney Bean. 8396 Cotter, Marion Co.; 10592 Washington, Hempstead Co.

Sesbania macrocarpa Nutt. Fulton, Hempstead Co. (4405 J. M. Greenman).

Stizolobium Deeringianum Bort. Velvet Bean. McNab, Hempstead Co. (4436 J. M. Greenman).

Wistaria macrostachya Nutt. Fulton and McNab, Hempstead Co.

Strophostyles umbellata (Muhl.) Britton. 12655 McNab, Hempstead Co.

Strophostyles helvola (L.) Britton. Fayetteville, Washington Co.

Trifolium hybridum L. Alsike Clover. Fayetteville, Washington Co. Introduced. (R. H. Austin).

Trifolium dubium Sibth. Fayetteville, Washington Co.; Eagle Mills, Ouachita Co. Introduced.

Vicia angustifolia (L.) Richard. 24510 Hot Springs, Garland Co. Introduced.

Vicia sativa L. Fayetteville, Washington Co. Introduced.

Vicia tetrasperma (L.) Moench. 5395 Fulton, Hempstead Co. Introduced.

Geraniaceae:

Erodium cicutarium (L.) L'Hér. University of Arkansas campus, Fayetteville (A. D. Oxley).

Geranium pusillum Burm. f. University of Arkansas campus, Fayetteville.

Oxalidaceae:

Oxalis Brittonae Small. England, Lonoke Co.

Oxalis texana (Small) Fedde. Introduced in favored places or as weed in greenhouses.

Oxalis Langliosii (Small) Fedde. Fayetteville, Washington Co.

Oxalis interior (Small) Fedde. Benton Co. (type locality) (E. N. Plank).

Linaceae:

Linum medium (Planch.) Small. Hazen, Prairie Co. (Roland M. Harper).

Zygophyllaceae:

Tribulus terrestris L. Ft. Smith, Sebastian Co.; 6094 Corning, Clay Co.

Rutaceae:

Ptelea polyadenia Greene. 5923, 5921 Cotter, Marion Co.; 6957 Heber Springs, Cleburne Co.

Zanthoxyllum americanum Mill. Savoy, Washington Co.

Meliaceae:

Melia Azedarach L. Escaped from cultivation, Fulton, Hempstead Co.

Euphorbiaceae:

Andrachne phyllanthoides (Nutt.) Muell. Arg. 5528 Eureka Springs, 27053 Berryville, Carroll Co.; Magazine Mtn., Logan Co.; Hot Springs, Garland Co.

Croton Engelmanni var. *albinoides* Ferg. Ful ton, Hempstead Co.; Texarkana, Miller Co.; Ashdown, Little River Co.

Crotonopsis elliptica Willd. 6962 Heber Springs, Cleburne Co., also common in barrens of Ozark region.

Euphorbia arkansana Engelm. & Gray. (*Tithymalus arkansanus* Kl. & Garcke). Clark Co. (C. Woolsey).

Euphorbia commutata Engelm. (*Tithymalus commutatus* Kl. & Garcke). Eureka Springs, Carroll Co. (C. Woolsey).

Euphorbia Nuttallii Engelm. (*Chamaesyce Nuttallii* Small). 6333 Beaver, Carroll Co.

Tragia ramosa Torr. 4382 Eureka Springs, Carroll Co.

Anacardiaceae:

Cotinus americanus Nutt. American Smoke-tree, Chittamwood. 5971, 10556 Cotter, Marion Co.; Van Buren, Crawford Co. (G. M. Brown).

Rhus trilobata Nutt. Polecat-bush. (*Schmaltzia trilobata* Small). 4384 Eureka Springs, Carroll Co.; 4754, 8411 Cotter, Marion Co. Common on rocky bluffs of Ozark region. *Schmaltzia serotina* Greene also occurs in the northern part of the state and may be distinct.

Rhus quercifolia (Michx.) Steud. Poison Oak. 258 Rich Mountain, Polk Co.; 24810 Blue Mountain, Logan Co.; 25052 Hazen, Prairie Co.

Aquifoliaceae:

Ilex caroliniana (Walt.) Trel. 12661, 14648 McNab, Hempstead Co.; 23060 Hot Springs, Garland Co.; Cove Creek, Faulkner Co.

Aceraceae:

Acer floridanum (Chapm.) Pax. McNab, Hempstead Co.; Crowley's Ridge (Roland M. Harper).

Acer leucoderme Small. 24508, 26474, etc. Hot Springs, Garland Co.; Baker Springs, Howard Co. (J. H. Kellogg).

Acer saccharum var. *glaucum* (Pax.) Sarg. 14313 Cotter, Marion Co.; 20488 Eureka Springs, Carroll Co. The common Sugar Maple of the state.

Acer saccharum var. *Rugellii* (Pax.) Rehd. Eureka Springs, Carroll Co.; near Hindsville, Madison Co.

Acer rubrum var. *Drummondii* (Hook. & Arn.) Sarg. (*Acer Drummondii* Hook. & Arn.) 7164 Fulton, Hempstead Co.; St. Francis River swamps (S. M. Coulter).

Acer rubrum var. *tridens* Wood. 8364 Ashdown Little River Co.; Fulton, Hempstead Co.

Acer Negundo var. *texanum* Pax. 6977 Heber Springs, Cleburne Co.; 8072 Arkadelphia, Clark Co.; 14639 Cotter, Marion Co.; 22261 Fulton, Hempstead Co. The form *latifolia* Sarg. is also found at Fulton.

Hypocastanaceae:

Aesculus discolor var. *mollis* Sarg. Red-flowered Buckeye. (*Aesculus austrina* Small). 8078 Gum Springs, Clark Co.: Austin, Lonoke Co.; Fulton, Hempstead Co. Common over the state except in parts of the Ozark region.

Aesculus glabra var. *micrantha* Sarg. Fulton, Hempstead Co. (type locality).

Aesculus glabra var. *pallida* Kirch. 8203 Winslow, Washington Co.

Aesculus glabra var. *leucodermis* Sarg. (Reported by Harvey as *A. glabra*). Fayetteville, Washington Co.; 4442 Eureka Springs, Carroll Co.

X *Aesculus Bushii* Schneider. Fulton, Hempstead Co. (type locality). (B. F. Bush). A supposed hybrid between *A. glabra* var. *leiodermis* and *A. discolor* var. *mollis*.

Sapindaceae:

Sapindus Drummondii Hook & Arn. 5949 Cotter, Marion Co.; Fulton, Hempstead Co.; Savoy, Washington Co.

Rhamnaceae:

Ceanothus ovatus Desf. 21015 Van Buren, Crawford Co.; Farmington, Washington Co.

Ceanothus pubescens (T. & G.) Rydb. North Arkansas, exposed limestone ledges.

Rhamnus lanceolata Pursh. 5931, (17239) Cotter, Marion Co.; 20495 Eureka Springs, Carroll Co.

Vitaceae:

Ampelopsis cordata Michx. False Grape. Fayetteville, Washington Co.; 5933 Cotter, Marion Co.

Parthenocissus quinquefolia var. *hirsuta* (Don.) Planch. 216 Huntsville, Madison Co.; 22189, 22209. Van Buren, Crawford Co.

Parthenocissus quinquefolia var. *Saint-Paulii* (Koehne & Graebn.) Rehd. 5909 Cotter, Marion Co.; 22269 Fulton, Hempstead Co.

Vitis cinera Engelm. Winter Grape. 5932 Cotter, Marion Co. Common throughout state.

Vitis Linsecomii var. *glauca* Munson. Post Oak Grape. 5554 Eureka Springs, Carroll Co.; 22191 Van Buren, Crawford Co.; 228 McNab, Hempstead Co.; Fayetteville, Washington Co.

Vitis rotundifolia Michx. Muscadine. Conway, Faulkner Co.; 257 Rich Mountain, Polk Co.; Forrest City, St. Francis Co.; 6839 Columbus, Hempstead Co.; 8470 Gifford, Hot Springs Co.; 6956 Heber Springs, Cleburne Co.

Vitis palmata Vahl. 6052 Corning, Clay Co.; 10526 Ft. Lynn, Miller Co.; 12667 McNab, Hempstead Co.

Tiliaceae:

Tila caroliniana Mill. 16336 McNab, Hempstead Co.

Tilia caroliniana var. *rhoophila* Sarg. 8074 Gum Springs, Clark Co.

Tilia floridana Small. (*Tilia pubesceus* Ait., reported by Coville, may belong here). 7204, 9401 McNab, Hempstead Co.; 20512 Eureka Springs, Carroll Co.; 20657 Cotter, Marion Co.; 20729 Gum-Springs, Clark Co.

Tilia floridana var. *hypoleuca* Sarg. 5943 Cotter, Marion Co.; Kessler Mountain near Farmington, Washington Co.

Tilia nuda Sarg. Fulton, Hempstead Co.

Malvaceae:

Callirhoe alcaeoides (Michx.) Gray. University of Arkansas campus, Fayetteville.

Callirhoe Bushii Fernald. Baldwin, Savoy, Washington Co.

Callirhoe triangulata (Leavenworth) Gray. 5977 Cotter, Marion Co.

Hibiscus incanus Wendl. 466, 16321 Fulton, Hempstead Co.

Hibiscus lasiocarpus Cav. 8365 Ashdown, Little River Co.; 26638 Helena, Phillips Co.

Malvastrum angustatum Gray. 6910 Harrison, Boone Co.

Hypericaceae:

Ascyrum multicaule Michx. 22289 McNab, Hempstead Co.

Hypericum apocynifolium Small. Hazen, Prairie Co. and S. E. coastal plain. (Roland M. Harper).

Hypericum pseudomaculatum Bush. Fayetteville, Washington Co.; 5957 Cotter, Baxter Co.; 8155 Ozark, Franklin Co.

Hypericum oklahomense E. J. Palmer. Cove Creek, Faulkner Co.

Cistaceae:

Lechea villosa Ell. 8122 Malvern, Hot Springs Co.

Helianthemum rosmarinifolium Pursh. 8162 Piney, Johnson Co.

Violaceae:

Viola eriocarpa Schwein. Johnson and Elm Springs, Washington Co. (*V. pubescens* Ait, of Branner and Coville, probably belongs here).

Viola fimbriatula J. E. Sm. 420 and 7153 McNab, Hempstead Co.

Viola Lovelliana Brainerd. Mena, Polk Co. (E. Brainerd).

Viola missouriensis Greene. Osage Creek, Washington Co.; Benton Co.; 5393, 7165, Fulton, Hempstead Co.

Viola primulifolia L. Washington, Hempstead Co.; West Mountain near Hot Springs, Garland Co.

Viola sororia Willd. Fayetteville, Washington Co.; 4782 Moark, Clay Co.

Viola triloba Schwein. (This may be Harvey's var. *cordata*). Mt. Comfort, Washington Co.; 5374, 7150, 9390 Fulton, Hempstead Co.

Viola triloba var. *dilatata* (Ell.) Brainerd. Mena, Polk Co., West Fork, Washington Co.; (Westville, Okla. E. Brainerd).

Viola papilionacea Pursh. 24465 Hot Springs, Garland Co.; Fayetteville, Washington Co.; Mena, Polk Co. (E. Brainerd).

Viola striata Ait. Fayetteville, Washington Co.

Viola viarum Pollard. Along White River. (E. Brainerd).

Lythraceae:

Cuphea petiolata (L.) Koehne. (*Parsonsia petiolata* Rusby). 4423 Eureka Springs, Carroll Co.

Onagraceae:

Oenothera linearis Michx. (*Kneiffia linearis* Spach). Fayetteville, Washington Co.; 23218 Top of Magazine Mountain, Logan Co.; 5404 Fulton, Hempstead Co.

Oenothera missouriensis Sims. (*Megapterium missouriense* Spach). Eureka Springs, Carroll Co.

Oenothera arenicola (Small) Coker. (*Kneiffia arenicola* Small). 25038 Hazen, Prairie Co.

Cornaceae:

Cornus alternifolia L. Sylamore, Stone Co. (W. W. Ashe), also in Washington Co.

Cornus stricta Lam. 6090 Corning, 10591 Moark, Clay Co.; 12649a Mena, Polk Co.; 8363 Ashdown, Little River Co.; 16324 Fulton, Hempstead Co.

Umbelliferae:

Ammoselinum Butleri (Engelm.) Coult. & Rose. Credited to State in Coulter & Rose, Monograph of Umbelliferae.

Angelica villosa (Walt.) B. S. P. 6024 Rush, Marion Co.

Chaerophyllum texanum Coult. & Rose. 5409 Fulton, Hempstead Co.

Daucus Carota L. Along roadsides and railroads, Fayetteville, Washington Co.

Erigenia bulbosa (Michx.) Nutt. West Fork, Washington Co.

Eryngium prostratum Nutt. 6048 Corning, Clay Co.; 8166 London, Pope Co.

Hydrocotyle bonariensis Lam. Coastal Plain of Arkansas. (Roland M. Harper).

Ptilimnium Nuttallii (DC.) Britton. 8027 Fulton, Hempstead Co.; 8164 Piney, Johnson Co.

Ptilimnium capillaceum (Michx.) Raf. 26682 Jonesboro, Craighead Co.

Sium suave Walt. (*Sium cicutaefolium* Schrank). St. Francis River swamps. (S. M. Coulter).

Torilis Anthriscus (L.) Bernh. Fayetteville, Washington Co. (Miss C. Chandler).

Zizia aurea (L.) Koch. 5559 Eureka Springs, Carroll Co.

Zizia cordata (Walt.) DC. 5557 Eureka Springs, Carroll Co.

SYMPETALAE.

Ericaceae:

Monotropa Hypopitys L. (*Hypopitys americana* Small). Prarie View, Washington Co., densely wooded north slopes of chert hills.

Rhododendron oblongifolium (Small) Millais. Azalea, Honeysuckle. (*Azalea oblongifolia* Small). 6932 Jasper, Newton Co.; 6973 Heber Springs, Cleburne County; 10505 Columbus, Hempstead Co.; 10515 Doddridge, Miller Co.

Rhododendron roseum (Loisel.) Rehd. Azalea, Honeysuckle. 260 Rich Mountain, Polk Co.; 26466 Meaford, Garland Co.; Batesville, Independence Co.; Cove Creek, Faulkner Co.

Rhododendron canescens (Michx.) G. Don (*Azalea canescens* Michx.). Yellville, Marion Co.

Vaccinium arboreum var. *glaucescens* (Greene) Sarg. (*Batodendron glaucescens* Greene). 6942 Jasper, Newton Co.

Vaccinium vacillans Kalm. Fulton, Hempstead Co. and occasional through Ozark region, but much less common than the following variety.

Vaccinium vacillans var. *crinitum* Fernald. 5556 Eureka Springs, Carroll Co.; 5989 Cotter, Marion Co. Common throughout Ozark region.

Primulaceae:

Dodecatheon brachycarpa Small. Wheeler, Washington Co.

Steironema intermedium Kearney. Fayetteville, Washington Co.

Sapotaceae:

Bumelia lycioides (L.) Pers. 25137, 26649 Helena, Phillips Co.; 26725 McNab, Hempstead Co.

Ebenaceae:

Diospyros virginiana var. *platycarpa* Sarg. Large-fruited Persimmon. 20669 Cotter, Marion Co., also in northwestern counties.

Styracaceae:

Halesia monticola var. *vestita* Sarg. Silver-bell Tree. 255 Rich Mountain, Polk Co.; 6978 Heber Springs, Cleburne Co.; 24926 Hot Springs, Garland Co.

Oleaceae:

Forestiera acuminata var. *vestita* E. J. Palmer. Miller Co. (type by Bush); Fulton, Hempstead Co.; Van Buren, Crawford Co.

Ligustrum vulgare L. Privet. 14321 Cotter, Marion Co. Escaped from cultivation.

Fraxinus pennsylvanica var. *lanceolata* (Borck.) Sarg. Green Ash. 6073 Corning, Clay Co.; 5942 Cotter, Marion Co.; 8080 Arkadelphia, Clark Co.; Fayetteville, Washington Co. Common along streams throughout state.

Fraxinus profunda Bush. Pumpkin Ash. 6067 Corning, Clay Co.; St. Francis River swamps (S. M. Coulter).

According to Harvey, *Fraxinus nigra* Marsh (*F. sambucifolia* L.) is found in Arkansas. This is probably an error which has been repeated by others.

No specimens are to be found in any of the American herbaria and Harvey left no specimens in the University of Arkansas collections.

Gentianaceae:

Bartonia virginica (L.) B. S. P. 10586 Washington, Hempstead Co.; 26476 Lonsdale, Garland Co.

Centaurium texense (Griseb.) Fernald. (*Erythraea texensis* Griseb. Northern Arkansas border counties.

Gentiana flavida Gray. (*Dasystephena flavida* Britton.) Magazine Mountain, Logan Co.

Apocynaceae:

Amsonia ludoviciana Vail. Fayetteville, Washington Co.; Lonoke, Lonoke Co.

Apocynum cannabinum var. *pubescens* (R. Br.) DC. 6092 Corning, Clay Co.

Vinca minor L. Periwinkle or Myrtle. Washington Co. Escaped locally from cultivation.

Asclepiadaceae:

Asclepias stenophylla Gray. 8397 Cotter, Marion Co.

Asclepias Sullivantii Engelm. Fayetteville, Washington Co.

Asclepias perennis Walt. Corning, Clay Co.

Asclepias purpurascens L. 12648 Mena, Polk Co.

Acerates floridana (Lam.) Hitchc. 25018 Hazen, Prairie Co.

Convolvulaceae:

Cuscuta cuspidata Engelm. 16322 Fulton, Hempstead Co.

Stylisma humistrata (Walt.) Chapman. 8111 Gifford, Hot Springs Co.

Polemoniaceae:

Phlox bifida Beck. War Eagle Creek near Huntsville, Madison Co.

Hydrophyllaceae:

Nemophila phacelioides Nutt. Wheeler and Johnson, Washington Co.; Hot Springs, Garland Co.

Boraginaceae:

Onosmodium occidentale Mackenzie. 8039 Fulton, Hempstead Co.; Baxter Mountain, Washington Co.

Onosmodium subsetosum Mack. & Bush. 6041a Northfork, Baxter Co.

Verbenaceae:

Verbena Drummondii (Lindl.) Baxt. Savoy, Washington Co.

Verbena Lambertii Sims. Son's Chapel, Washington Co.

Labiatae:

Satureja glabella (Michx.) Briquet. (*Clinopodium glabellum* Kuntze). West Fork, Washington Co., on calcareous outcrops.

Lamium purpureum L. Fayetteville, Washington Co. Introduced.

Monarda citriodora Cerv. Sulphur Springs, Benton Co.

Perilla frutescens (L.) Britton. 4437 Eureka Springs, Carroll Co.; Monte Ne, Benton Co.; Crowley's Ridge, near Forrest City, St. Francis Co. (Roland M. Harper).

Salvia azurea Lam. 451 McNab, Hempstead Co.

Salvia lanceifolia Poir. 4485 Eureka Springs, Carroll Co.

Solanaceae:

Datura Metel L. Egger, Polk Co. (R. H. Rosen). Introduced.

Physalis missouriensis Mack. & Bush. 6955 Fulton, Hempstead Co.

Bouchetia anomala (Miers) Britt. & Rusby. Summers, Washington Co., prairie glades.

Solanum elaeagnifolium Cav. 338 Texarkana, Miller Co.; Fayetteville, Washington Co.

Solanum Torreyi Gray. 23009 Pinnacle, Pulaski Co.

Scrophulariaceae:

Agalinis fasciculata (Ell.) Raf. 8464 Gifford, Hot Springs Co.; 8472 Gum Springs, Clark Co.

Buchnera elongata Sw. Prairies of Arkansas, coastal plain (Roland M. Harper).

Aureolaria grandiflora var. *serrata* (Torr.) Pennell. (*Dasystoma serrata* Small) 10603 Washington, 8977 McNab, Hempstead Co.

Linaria Cymbalaria (L.) Mill. Kenilworth Ivy. Fayetteville, Washington Co. Occasionally escaped.

Paulownia tomentosa (Thunb.) Steud. 10527 Ft. Lynn, Miller Co.; Monticello, Drew Co.; Hot Springs, Garland Co. Escaped from cultivation.

Pentstemon arkansanus Pennell. 8143 Little Rock, Pulaski Co.; 24556 Hot Springs, Garland Co.; 25167 Shirley, Van Buren Co.

Scrophularia neglecta Rydb. 12687 McNab, Hempstead Co.

Veronica arvensis L. Fayetteville, Washington Co. and throughout the state.

Veronica serpyllifolia L. Withrow Springs, Madison Co.

Veronica Tournefortii C. C. Gmel. Fayetteville, Washington Co., University of Arkansas campus.

Orobanchaceae:

Orobanche ludoviciana Nutt. (*Myzorrhiza ludoviciana* Rydb.) Kingdon Springs, Marion Co. (Roy Morrow).

Rubiaceae:

Cephalanthus occidentalis var. *pubescens* Raf. Fulton, Hempstead Co.; Hot Springs, Garland Co.

Galium tinctorium L. 6083 Corning, Clay Co.

Houstonia lanceolata (Poir.) Britton. Lee Co. (C. Woolsey).

Caprifoliaceae:

Lonicera japonica Thunb. Japanese Honeysuckle. Escaped in all parts of state and often becoming troublesome. Naturalized from Asia.

Sambucus canadensis var. *submollis* Rehder. 22295 McNab, Hempstead Co.

Viburnum affine Bush. Ozark region, on rocky cliffs.

Dipsacaceae:

Dipsacus sylvestris Huds. Teasel. Washington and Benton Counties. Introduced in waste places.

Cucurbitaceae:

Cucurbita foeditissima H. B. K. (*Pepo foetidissima* Britton) Washington and Benton Counties.

Echinocystis lobata Michx. *Micrampelis lobata* Greene) Washington Co.

Lobeliaceae:

Lobelia spicata var. *hirtella* (Ell.) Gray. 4407 Eureka Springs, Carroll Co.

Campanulaceae:

Sphenoclea zeylanica Gaertn. Lonoke, Lonoke Co.; Stuttgart, Arkansas Co. An introduced annual weed of rice fields.

Compositae:

Artemisia annua L. 4732 Cotter, Baxter Co.

Aster lateriflorus (L.) Britton. 26670 Helena, Phillips Co.

Aster ericoides L. 4510 Eureka Springs, Carroll Co.

Aster ericoides var. *pilosus* (Willd.) Porter. 6812 Fulton, Hempstead Co.; 6883 Eureka Springs, Carroll Co.

Aster salicifolius Lam. 8981 Fulton, Hempstead Co.

Aster subsessilis Burgess. Benton County (type locality, E. N. Plank).

Aster Tradescantii L. 4491 Eureka Springs, Carroll Co.; Moark, Clay Co.

Bidens discoidea (T. & G.) Britton. 26733 McNab, Hempstead Co.

Brauneria pallida (Nutt.) Britton. 25022 Hazen, Prairie Co.; Savoy, Washington Co. Common in Ozark region.

Cacalia similis (Small) new comb. (*Mesadenia similis* Small.) Benton Co. (type locality, E. N. Plank); Savoy, Washington Co.

Chrysopsis mariana (L.) Ell. Southeast Arkansas (County Agric. Agent).

Chrysopsis microcephala Small. 6847 Columbus, Washington Co.

Cirsium horridulum Michx. 24977 Fulton, Hempstead Co.

Coreopsis lanceolata var. *villosa* Michx. (*C. crassifolia* Ait.) 26889 Lawrence, Garland Co.; 27056 Berryville, Carroll Co.

Coreopsis pubescens Ell. Savoy, Greenland, Washington Co.; 4490 Beaver, 6350 Eureka Springs, Carroll Co.; Harrison, Boone Co.

Eupatorium incarnatum Walt. 4766 Cotter, Marion Co.; 14626 Texarkana, Miller Co.

Erigeron quercifolius Lam. Screeton, Prairie Co. (Roland M. Harper).

Gaillardia lutea Greene. 10596 Washington, Hempstead Co.

Helenium campestre Small. Little Rock, Pulaski Co. (type locality, coll. by Hasse, 1885); Conway, Faulkner Co. (H. E. Wheeler).

Helianthus divaricatus L. 12631 Mena, Polk Co. 26444 Magazine Mountain, Logan Co.; 29445 McNab, Hempstead Co.

Helianthus heterophyllus Nutt. 6979 Heber Springs, Cleburne Co.

Hymenopappus carolinensis (Lam.) Porter. 27052 Berryville, Carroll Co.

Lactuca canadensis L. Fayetteville, Washington Co.

Lactuca scariosa var. *integrata* Gren. & Godr. Common over entire state.

Liatris squarrosa var. *intermedia* (DC.) T. & G. 23061 Hot Springs, Garland Co.

Matricaria suaveolens (Pursh.) Buchenau. Fayetteville, Wheeler, Washington Co. Introduced.

Mikania scandens (L.) Willd. St. Francis River Swamps (S. M. Coulter).

Parthenium hispidum Raf. (*Parthenium repens* Eggert). 5591 Beaver, 27059 Berryville, Carroll Co.

Pluchea petiolata Cass. 314 Texarkana, Miller Co.; 4756 Cotter, Marion Co.

Verbesina virginica L. 274 Rich Mountain (at summit), Polk Co.

Lepachys columnaris (Sims) T. & G. Prairie Grove, Washington Co.; 8024 Fulton, Hempstead Co.; 8216 Benton, Saline Co.

Rudbeckia Brittonii Small. Fayetteville, Washington Co.

Senecio obovatus var. *rotundus* Britton. 7201 McNab, Hempstead Co.; 26866 Hot Springs, Garland Co.; 24444 Little Rock, Pulaski Co.

Senecio plattensis Nutt. Prairie, near Hazen, Prairie Co. (fide J. M. Greenman). A noxious weed.

Silphium Gatesii Small. 8048 McNab, Hempstead Co.

Solidago amplexicaulis T. & G. 434 McNab, Hempstead Co.

Solidago caesia var. *axillaris* (Pursh.) Gray 6930 Jasper, Newton Co.

Solidago celtidifolia Small. 8461 Gifford, Hot Springs Co.

Solidago arguta Ait. 26430 Magazine Mountain, Logan Co.

Solidago hispida Muhl. 6912 Harrison, Boone Co.; 26464 Lonsdale, Garland Co.

Solidago juncea Ait. 547 McNab, Hempstead Co.; 4401, 4368 Eureka Springs, Carroll Co.

Solidago latifolia L. (*Solidago flexicaulis* L.) 4554 Eureka Springs, Carroll Co.; 4779 Cotter, Marion Co.

Solidago Lindheimeriana Scheele. 20482 Eureka Springs, Carroll Co.

Solidago pendula Small. Benton Co. (Type locality, collected by E. N. Plank.)

Spilanthes americana var. *repens* (Walt.) A. H. Moore. (*Spilanthes repens.* Michx.) 6085 Corning, Clay Co.

Sonchus asper (L.) Hill. Lonoke and Arkansas Counties in rice fields; Conway, Faulkner Co.; Fayetteville, Washington Co.

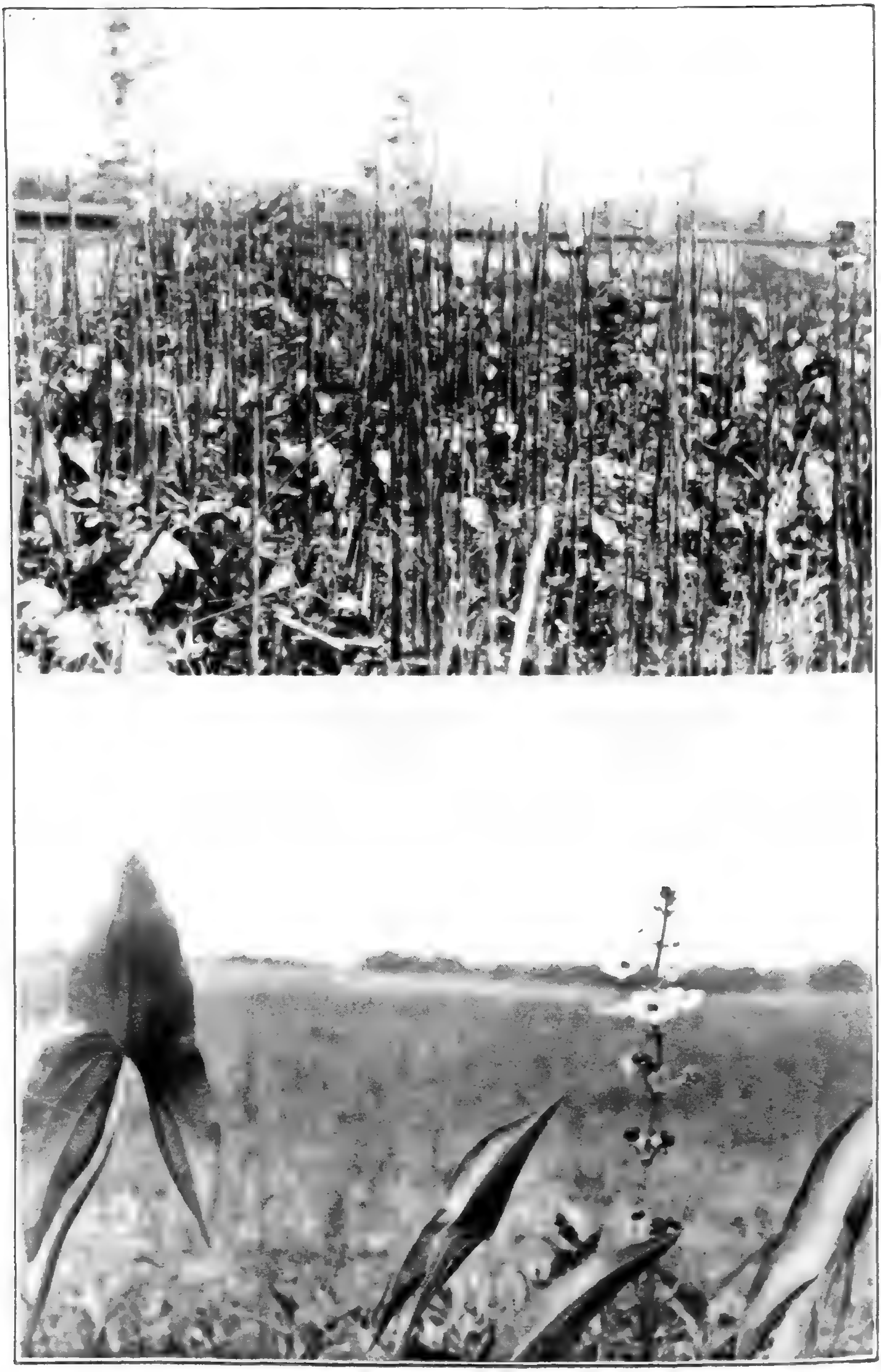
Sonchus oleraceus L. Fayetteville, Washington County and elsewhere (a common weed).

Tragopogon porrifolius L. Fayetteville, Washington Co. (as a weed).

Taraxacum erythrospermum Andrz. Conway, Faulkner Co.

Vernonia missurica Raf. 300 Texarkana, Miller Co.

Xanthium glabratum (DC.) Britton. 316 Texarkana, Miller Co.



EXPLANATION OF PLATE

PLATE VI

Upper: Scouring Rushes *(Equisetum praealtum)* along railway embankment near Palarm, Pulaski Co. (H. E. Wheeler.)

Lower: Arrow Leaf *(Sagittaria latifolia)* border of pond near Conway, Faulkner Co.

EXPLANATION OF PLATE

Plate VII

Upper left: Short Leaf Pine *(Pinus echinata)* in characteristic stand, about 25 years old. Butterfield, Ark.

Upper right: Same growing on quartzite hills along Ouachita River, Garland Co.

Lower left: Fringe Tree or Old Man's Beard *(Chionanthus virginica)* top of Magazine Mountain, Logan Co.

Lower right: Southern Buckthorn *(Bumelia lycoides),* Crowley's Ridge, near Helena, Phillips Co.

EXPLANATION OF PLATE

Plate VIII

Left: Texan Saxifrage *(Saxifraga texana)* probably the earliest spring flower, appearing late in February, Conway, Faulkner Co. x ½.

Middle: A very rare Wake Robin *(Trillium pusillum)* appearing in April in oak woods on flinty soil. Tontitown, Washington Co. x ⅓.

Right: False Aloe *(Agave virginica)* flowering in June, near Fayetteville, Washington Co.

EXPLANATION OF PLATE

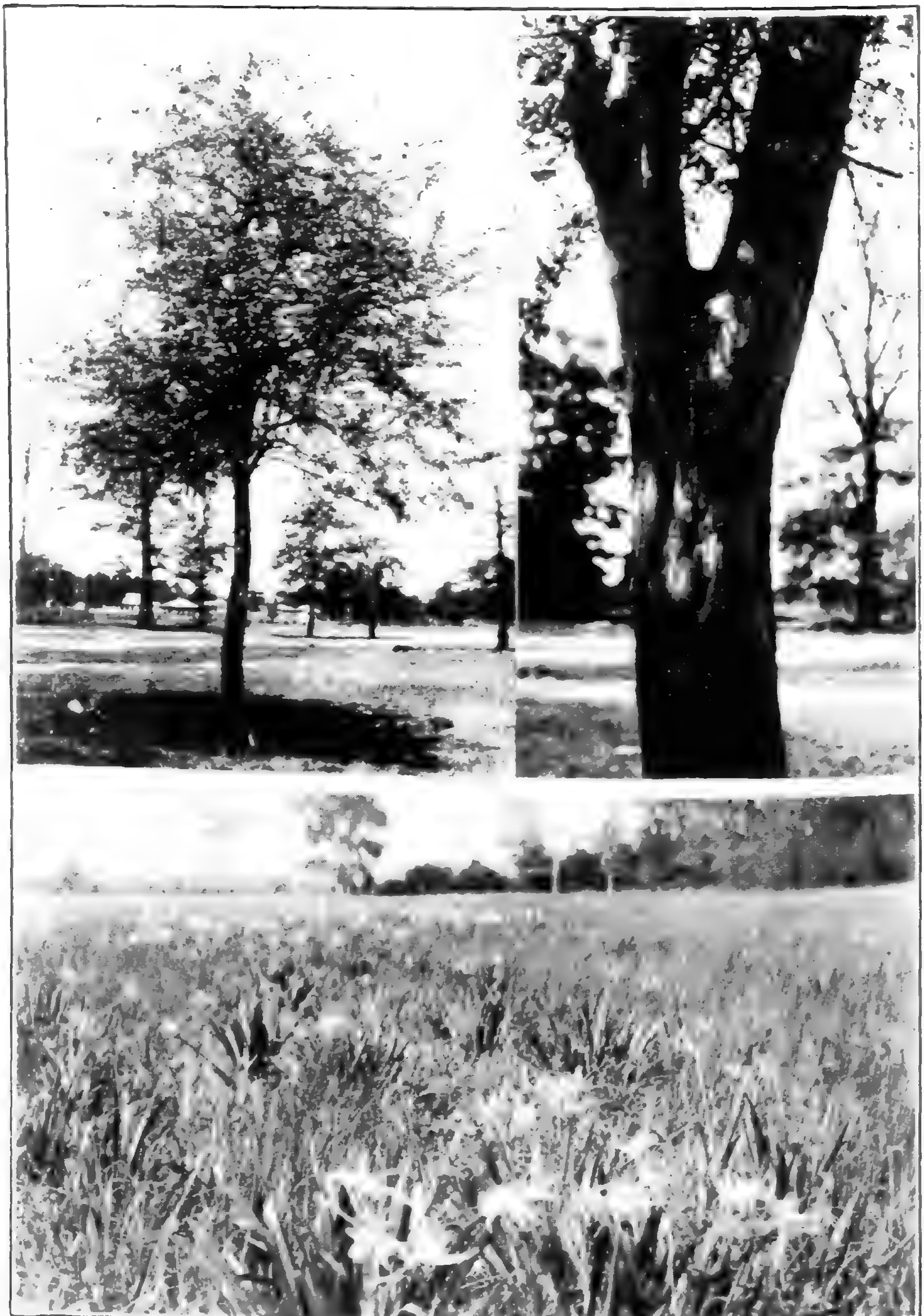
Plate IX

Upper left: Indian Plantain *(Cacalia tuberosa)* near Imboden.

Upper right: Fly Poison *(Amianthium muscaetoxicum)* near Imboden, Lawrence Co. (H. E. Wheeler.)

Lower left: Large tree of the Ozark Chinquapin *(Castanea ozarkensis)* near Farmington, Washington Co.

Lower right: Bark of Ozark Chinquapin, same tree as above.



EXPLANATION OF PLATE

Plate X

Upper left: Blue-fruited Hawthorn *(Crataegus brachyacantha)* near Texarkana, Miller Co.

Upper right: Bark of same.

Below: Field of Spider Lilies *(Hymenocallis occidentalis and Iris)* in a marsh near Palarm, Pulaski Co. (H. E. Wheeler.)

EXPLANATION OF PLATE

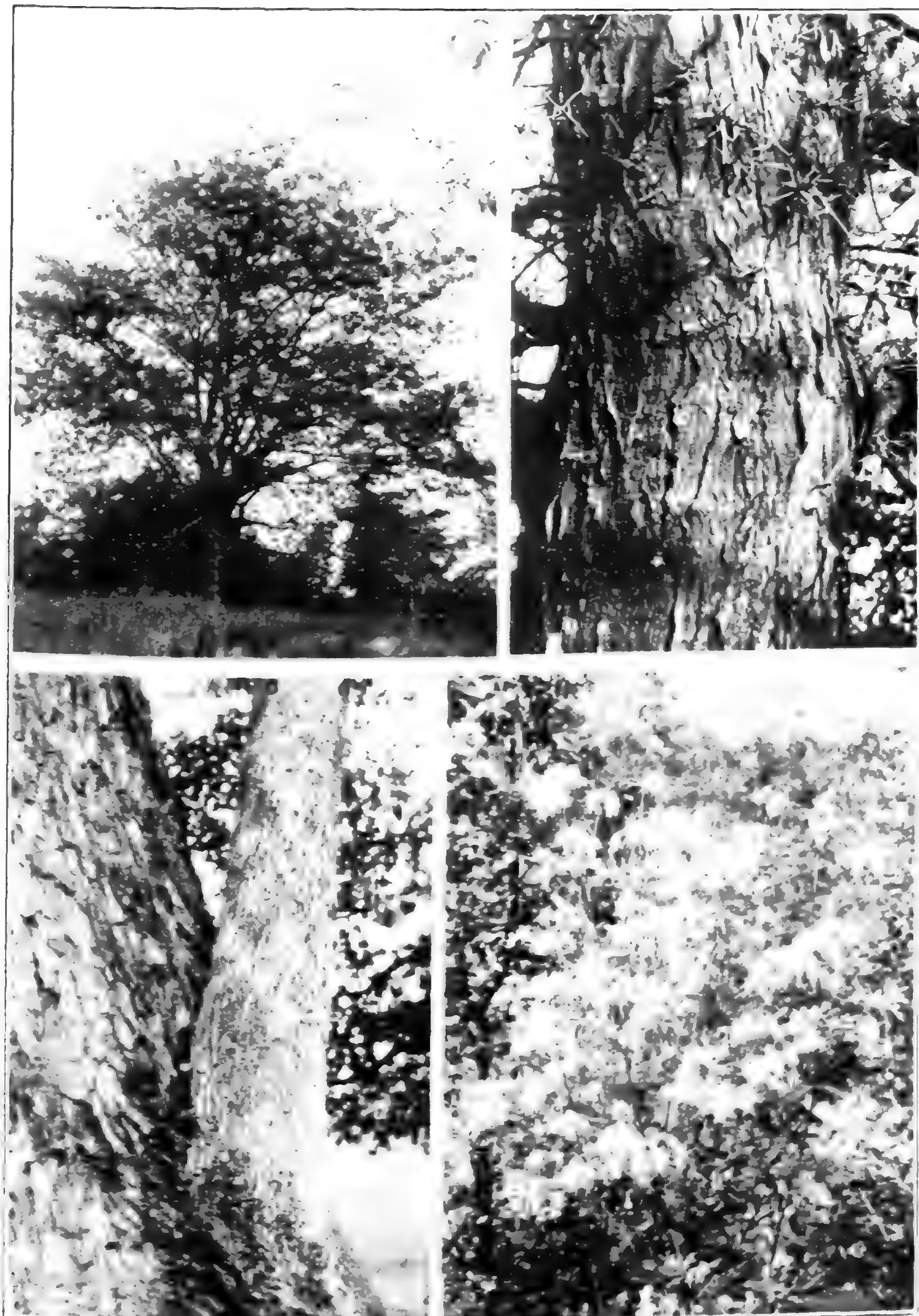
Plate XI

Upper left: Honey Locust *(Gleditsia triacanthos)* near Helena, Phillips Co.

Upper right: Bark of same.

Lower left: White Ash *(Fraxinus americana)* growing from opening in trunk of hollow Post Oak *(Quercus stellata)* Fulton, Hempstead Co.

Lower right: Azalea *(Rhododendron canescens)* in April near Hot Springs.



EXPLANATION OF PLATE

Plate XII

Upper left: Blazing Star *(Liatris elegans)* and Button Snakeroot *(Eryngium yuccaefolium)* in a meadow near Palarm, Pulaski Co.

Upper right: Chicasaw Plum *(Prunus angustifolia)* growing on loess hills, Helena, Phillips Co.

Lower left: Short Leaf Pine *(Pinus echinata)* West Mountain, Hot Springs.

Lower right: French Mulberry *(Callicarpa americana)* a shrub with brilliant lavender colored berries in autumn. Helena, Phillips Co.

EXPLANATION OF PLATE

PLATE XIII

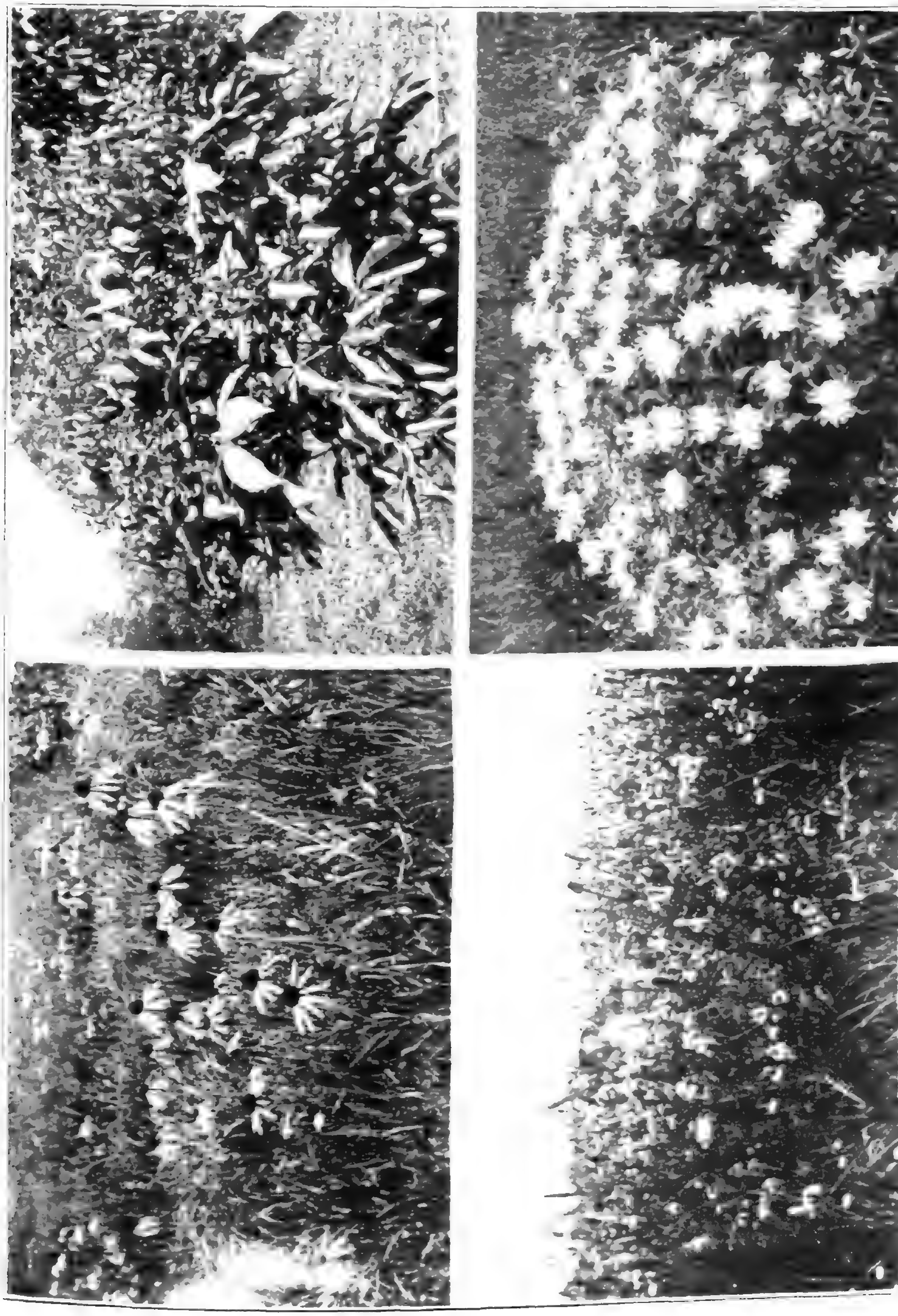
Upper left: Cone Flower *(Brauneria pallida)* in a meadow in May, Washington Co.

Upper right: Red Buckeye *(Aesculus discolor* var. *mollis)* flowering in May, Central Arkansas.

Lower left: Prairie Clover *(Petalostemon purpureum)* in June, Northwest Arkansas.

Lower right: Rough Bergamot *(Monarda scabra)* Arkansas border and Southwestern Missouri in June.

PLATE XIII



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THE ECOLOGY OF A SHELTERED CLAY BANK; A STUDY IN INSECT SOCIOLOGY

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THE ECOLOGY OF A SHELTERED CLAY BANK; A STUDY IN INSECT SOCIOLOGY.

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(A) INTRODUCTION.

"Living things are real things—but their reality is in their interrelations with the rest of nature, and not in themselves."—Brooks.

The ecologist, when he wishes to study the interrelations of a fauna to a restricted area, usually selects a virgin plot, uncontaminated and undisturbed by the hand of man. The area which I have studied is unique in that it has been created by man. These pages will reveal that the invertebrate population readily responded to this man-made habitat and lost no opportunity to utilize it to advantage. Despite the fact that the clay bank here referred to was artificially built, the attraction to it of the life about the area for nesting and other purposes was legitimate, and this made the place a biotic unit of unusual interest.

I have given to the unit a layman's study of ecology, made without the technical and refined instrumental examinations and prepared without the use of new and complex terms so often introduced into a study of this kind, which, in my opinion take commonplace phenomena and place them beyond the understanding of the layman. By trying to become familiar with complex and unusual terms, one often loses the thread of the story of the interrelations of the inhabitants. In other words, this paper is, I hope, analogous to the study of the stars through an opera glass, instead of a study by mathematical formulae.

The ecological unit under discussion lay in a little valley at the station of Wickes, twenty-two miles south of St. Louis on the Iron Mountain Railroad. The Meramec River empties into the Mississippi about one-third of a mile northeast of this point. This region is attractive to fishermen and as a result about a dozen clubhouses have been built near the station. Some of these cottages were built upon posts or stilts, thus exposing the earth beneath them. Two such houses were situated on a northward slope, but there was no perceptible life in the earth under them. This was probably due to their shaded condition and the friable nature of the earth there. In the construction of another of these houses, a quantity of clay had been excavated from the cellar and had been shoveled under the porch to save the expense of hauling it away. In the twelve years that this heap of subsoil had lain there, it had become packed to a very hard consistency. The house faced the east where it received the benefits of the morning sun. The porch was four to five feet above the ground, and thus admitted a flood of light in the morning and midday, but excluded all the afternoon sun, and afforded protection from the weather. This bank of hard-packed yellow clay was about eighteen feet long, and varied from thirty to thirty-six inches in height. The wood-boring inhabitants of the porch, the life in the clay bank, the insects among the rubbish on top, the occupants of the rambler-rose stems in front of the bank, and the occasional visitors all constituted a legitimate biotic unit, the subject of this study. (See Fig. 2.)

In May, 1917, when the unit was first discovered, it was noted that the northern half of the clay bank was riddled with holes, while the south half was not so, but at the extreme south end a few turrets of a wild bee were found. Figs. 3 and 4 show the south and the north half of the clay bank respectively, and the enormous amount of activity which occurred in the north half in contrast to that in the south half will be seen by the contrast of the great number of holes in the one to the lack of them in the other. Before the summer was far advanced, the cause for the occupancy of one portion of the bank and not of its opposite half was clearly apparent. A glance at Fig. 2 will show how the central and south rose-bushes had been trained to overshadow the southern portion of the clay bank, while the third bush had been so bent as to leave the northern half exposed to the eastern sun.* This shows beautifully the relation of sunlight to the activities of Hymenoptera. The loose appellation usually applied to them, "Children of the Sun," is here seen to have truthful significance. It is generally known that bees and wasps love the sunlight, but a glance at Figs. 3 and 4 will forcibly emphasize this impression.

While this clay bank was small and unimposing, its riddled portions indicated that many bees and in all probability their parasites were potentially present, and for an ecological unit for intensive study nothing better could be wanted. Accordingly, frequent visits were made to the spot from June 5 to October 3, 1917, and several trips were made there for comparative data during the summers from 1918 to 1921.

When one looks at Fig. 2 and thinks of the life, love and death tragedies enacted within the limits of an area of a few square feet, one can see very clearly a literal example of the statement by Adams: "We may profitably compare an association of animals in a given habitat to a play upon the stage. The environment corresponds to

*The photograph for figure 2 was taken in October, when most of the leaves had fallen, and so does not give an adequate idea of the density of the shade.

the stage, the dominant members of the association correspond to the leading characters; the secondary species, always present, to the essential but subordinate characters. The individual animals adjust themselves to one another, especially to the dominant forms, and to the environment, as the personalities in the play adjust themselves to the dominant characters, to one another, and to the environment.. In both groups some individuals are dominant, some used and useful, some tolerated, others pick up the crumbs, still others are predatory or parasitic, and all must be mutually adjusted to one another and to the environment.''*

How this classification of various types fits into what we here record, the reader may presently see for himself.

(B) INTERRELATIONS OF ANIMAL LIFE.

(a) Fauna of the unit.

If all the bank's a stage, and all the six and eight-legged creatures merely players, it is fitting that we should give now a cast of characters, in the order of their importance, and follow the careers of the dominant ones for the five years, 1917 to 1921. Early in the work it was seen that the many insects did not use the clay bank and the environs in the same way, but they were easily classifiable into four distinct groups.

Group 1. Pioneers. The permanent dwellers in the clay bank and environs, in a general way the pioneers.

Group 2. Renters. The insects less hardy and more ease-desiring than the pioneers; those which rented or appropriated the abandoned dwellings of the pioneers. They might be called squatters.

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*Guide to the Study of Ecology, p. 47. 1913.

Group 3. Visitors. The insects and animals which dropped into the community accidentally, or in quest of shelter or food. They very often influenced the inhabitants, the members of groups 1 and 2, in two ways: by eating them or by becoming food for them.

Group 4. Parasites. This contains the names of parasites whose hosts are listed in groups 1 and 2.

(b) Pioneer life on the clay bank.

The pioneers, those which blazed the trail, those which first came from elsewhere and discovered the clay bank and homesteaded it, and made it easy for others following to live near them or in their old abodes, or to parasitize their children—these are first considered, and are listed in order of their importance. With this pioneer life as a foundation for a community, the other chapters that follow will point out their interrelations, sometimes simple, sometimes indifferent and sometimes complex.

The carpenter-bee, *Xylocopa virginica.* Drury.*

In the Spring of 1917, the place was visited at intervals to fix the date of the appearance of the first life. The carpenter-bee, *Xylocopa virginica,* was the first to appear. On June 15, perhaps a dozen of the insects were at work enlarging the tunnels in the wooden rafters of the porch above the clay bank. They were all doing precisely the same thing at this time, enlarging the holes and kicking out the sawdust. The flickering streams of golden grains falling in the sunlight from sources unseen would have attracted the attention even of persons unaccustomed to observations of this kind. Judging from

*All of the material has been identified by expert entomologists, whose names appear in brackets along with the specific name of the insect.

the piles of sawdust here and there on the ground, this work must have been going on for a good many days. Hence the emergence of the bees was simultaneous, but whether from hibernation or from the pupal stage I do not know, since I could not ascertain just how this species spends the winter, unless I used an ax on the rafters, and this I had not the immoral courage to do. However, it was plain from the first that no new tunnels were being made, but that old ones were being enlarged.

The activities of the bees in tunneling and pollen-gathering increased, although not their number, up to July 16, when they almost completely disappeared. This was probably the end of the first generation of 1917, regardless of whether they had hibernated or had emerged as new adults in the spring.

On July 30, other adults appeared—probably the first of the second generation. On this first day, two females were at work; on the next day four were in evidence, and the numbers continued to increase during the next few days, until by August 20 they were more abundant and seemed more industrious than the population earlier in the season. They were so intensely busy cutting out the tunnels, and they threw down the yellow dust to the ground in such abundance that the pits of the ant-lion larvae beneath suffered complete obliteration. They were seen in the same activity and numbers up to September 7 (with certain pauses in their work due to meteorological conditions described elsewhere). The three nights before September 12 were very cold; the insects about the unit were dwindling in numbers, and those which still lived were slow to come out of their burrows. That day it was 2 o'clock in the afternoon before the first carpenter bee made its appearance, but her sisters remained within, in either temporary or final rest. Again on September 23 only one carpenter-bee was seen. At this date all the other life was proportionately reduced, as was to be expected amid unfavorable weather conditions. A visit to the spot ten days later, October 3, revealed several dead specimens of these bees and other species about the bank, but no living ones. In all probability they were either dead in their burrows or closely huddled together, ready to hibernate for the winter.

In the year 1918, as I shall relate elsewhere, all the more important species in the unit appeared earlier than in the previous year. In 1917, the first carpenter-bees were sawing their tunnels on June 15; in 1918, on May 28 not only were they at work, but they had already completed their burrowing and were busily gathering the yellow pollen from the wild roses growing some distance away. The big shining black bee, heavily laden with bright yellow pollen, made a conspicuous bit of color, and was as pretty as the blossom itself. An examination showed that no new tunnels had been made, but the old ones from the last year had been again used.

My next visit on June 28 found no carpenter-bees out; this was probably the period between the two generations as was July 30 in 1917, when the first generation was late by a corresponding margin of time in getting a start. On July 17, when it seemed time to expect the second generation, I visited the colony, and found one lone carpenter-bee at work; July 31 likewise found only one bee out.

All of the evidence so far in 1918 indicated a marked reduction in the population of carpenter-bees. An abundance of shedding-skins of the silver-winged parasite, ***Argyromoeba tigrina,*** adhered to the wooden rafters about the bees' tunnels; hence it is probable that this parasite was largely responsible for the small number of bees, as well as of the mud wasps, *Monobia quadridens,* and the grass-carrier wasps, *Chlorion* (*Isodontia*) *auripes,* which occupied the old tunnels of the carpenter-bees. The details given later under the subject of parasites will show an enormous increase at that time in the number of adults of the *A. tigrina* parasite.

So the record for the second generation continued dismal; on August 31, barely two bees were busy, and by the middle of September none at all were to be seen.

During the summer of 1919 no observations could be made, so we do not know by what struggles or turns of fortune *Xylocopa* again came into her own, but in the following spring, on May 27,* 1920, they were once more fairly abundant. Their emergence had probably just occurred when I arrived upon the scene, for they were not tunneling, neither were they carrying pollen, but both sexes were in a gleeful mood of courtship. Several days later others were often seen refreshing themselves on the blackberry blossoms, while several returning females were so heavily laden with green pollen that much of it would spill in a delicate shower as they tried to gain entrance to the home. During the week of June 13 to June 19, eight mothers were at work on their nests. Since only these eight remained to work, out of the large number in the courtship dance, it leads one to suspect that a very large proportion of the latter group were males. During the days of June 28th and 29th, I kept a very careful watch and was startled by the revelation which met my eyes; during the two hours

*In 1922 they were flying about as early as April 7. One newly dead bee was taken from a spider's web.

from five to seven p. m., 35 adult *Xylocopa* returned to the colony and quietly crept into their burrows! This certainly shows how an observation must be made from every possible angle before one may dare to be satisfied with an answer. Fourteen of these were captured and examined; twelve were females and two were males. The presence of the males made me wonder whether they were the remainder of the first generation, or the forerunners of the second. I cannot imagine just what was their business abroad which kept them away from home all day thus, day after day, at a time when they were not gathering provisions of any kind for the nest. May it be that they were out seeking food to gorge and fatten themselves before beginning the arduous tasks of nidification? From this time on the population again waned, until by the middle of September they were seldom seen. Long after the others had disappeared from view, one lone mother was seen going into her burrow on October 13.

Just as the mining bees make way for numerous other species by bequeathing to them their old burrows, so *Xylocopa* makes it possible for two species of wasps, *Chlorion* (*Isodontia*) *auripes* and *Monobia quadridens* to inhabit the locality. For details of the behavior of these sub-tenants and for details of parasitism on the carpenter-bee, and for the relation of the bee to weather conditions, see later pages.

The mining bee, *Anthophora abrupta* Say [S. A. Rohwer].

The most important of the pioneers getting a foothold in the clay bank were two species of mining bees, one supplementing the other beautifully in the point of time.

The first to appear each year was *Anthophora abrupta*, and when its life cycle had run its course before the middle of the summer, the white-banded bee, *Entechnia taurea*, made its appearance. Other species of bees appeared from time to time, but none reached the importance that these two species attained.*

On June 25, 1917, it was found that several specimens of the mining-bee, *Anthophora abrupta* (Fig. 5), had emerged from their winter sleep in the depths of the clay bank, and were busily coming in and going out of their burrows. Some of these activities were directed to burrows which had mud chimneys at the openings, and some to others which had none. Some of these bees came in heavily laden with pollen; others had their gullets full of water; others were kicking out loose moist earth from their burrows and letting it fall to the ground below. Some were working within the burrows, and at intervals would come backing out with a ball of soft mud under the chin, toss it back to the hind pair of legs, and with only these appendages would fashion the wonderful little chimney which crowned the entrance; others were frequenting the puddle of water in a wagon rut near by, getting the water with which to moisten the hard yellow clay. Quite probably all these bees had emerged within a few days prior to June 25, and they were already at work in various stages of nest-building or provisioning. June 28 was my next visit, and this was after a heavy shower. There was little activity among the bees; most of them were waiting indoors until the sunshine should warm up the bank, but several had learned to make a

*In 1919, a third and new species of mining bee, *Anthophora raui*, appeared, and this has practically the same life cycle, and appears at the same time, or at most a few days later than *A. abrupta*.

lucky turn out of this misfortune; instead of going some distance to the roadway puddle for their water, a dozen bees with their long tongues protruding were lapping up the drops of water from the vegetation nearby.

Frequent visits showed the activity of the *A. abrupta* bees to be the same without change in numbers up to July 12. Thus the entire population lived practically simultaneously, without individual variation in time. During the four days from July 12 to 16, the number of workers dwindled alarmingly from day to day. This sudden dropping off led me to believe that I was witnessing the death and the end of the first generation. I hoped that the second generation would come soon enough and be large enough to give me material for certain homing studies without the danger of exterminating them. The next few days saw the demise of the last few survivors; but my anticipation of a second generation was in error, for no others appeared that year. Furthermore, in the years following I found only one generation of these bees each year, and that with a remarkably short life cycle. In this 1917 brood, the duration of adult life was less than thirty days, the first bees emerging a few days before June 25, and the last ones dying about July 16.

While daily visits during the following week proved that *A. abrupta* had entirely disappeared, these daily visits also made it conspicuously clear that another species of turret-building mining bee, *Entechnia taurea,* had emerged from the bank and was busily engaged in nest building activities. And in precisely the same way in the following years it was observed that just as soon as *A. abrupta* had finished her labors and gone the way of all flesh, then the white-banded bees appeared upon the scene. The interrelations of the two species of bees in point of numbers from year to year show very fine adjustment. As one species increased progressively from year to year, the other decreased. The details of this phenomenon are given on later pages.

While *A. abrupta* appeared about June 25 in 1917, a visit on May 28, 1918, showed this species already out and active. Early emergence this year affected most species inhabiting the bank. Later I shall discuss the relation of this emergence to meteorological conditions. But even at this early date, the *A. abrupta* bees must have emerged five or six days previously because the work on their chimneys was in many cases far advanced or completed. Having been born a month earlier in the year than their parents of the preceding year had been, the population had the same number of days to their adult life and lived, builded, and many had died before June 28. Then, within three days after their disappearance came the white-banded bees again, following with all the precision of clock-work! The interesting item was that *Anthophora abrupta* had increased in numbers from 22 nest-building mothers in 1917 to 92 in 1918.* Not all of the 92 mothers had nests with turrets; only 52 had full-sized chimneys, 15 with half-sized ones and 25 nested in burrows devoid of chimneys. This increase was, as we shall later show, very decidedly at the expense of the white-banded bees whose numbers this year rapidly decreased. What should we expect in the following year, and what was the cause of the change in dominance?

*It should be said here, that any accretions in numbers from year to year in this clay bank for *A. abrupta* were progeny from the original settlers, for a thorough search here for five years gave no evidence of another colony. For *Entechnia taurea* the same cannot be said, for within a mile, three struggling colonies were found, but since the latter species diminished in the bank from year to year, it is evident that no new stock took up their abode there.

In 1919, circumstances were such that I could pay my first visit to the clay bank only on September 6. Therefore, I could not get their date of emergence, but they had left for me a clearly-written record of their abundance on the face of the bank. I counted 232 turrets,* which indicated that at least that number of mothers had been at work. Since a small portion of the mothers used the burrows without turrets, and since some may have been broken down, this is a conservative number. I am sure that none were from the previous year, for I had harvested the entire lot in the autumn for my cabinet and study. A recapitulation of the figures is of interest: in 1917, 22; 1918, 92; 1919, 232.

In 1920, the first visit to the clay bank was made on May 28. Until 9:45 a. m. no bees appeared; then the sun warmed the bank and I saw two *A. abrupta* flying before the bank and entering numerous holes, one after the other. During the next fifteen minutes I sat before the bank and saw three others emerge from the burrows and dart away on the wing. The white faces of all five proved that they were males. A shrill voice within a burrow caused be to rivet my attention to a certain spot, where soon a sixth white face made its appearance. So here I was at hand for the first time to see the males emerge! There were no females about. There occurs in this species that which we see in so many species of insects—the priority of the emergence of the males. About noon the first female was seen going into burrow after burrow, and a little later a second one was doing precisely the same, while the males began to go away to

*This had been an especially wet year and the bees could get water for digging. In dry years, as in 1922, hardly any of them made turrets.

the blackberry blossoms, or to rest listlessly upon the nearby vegetation. The females moved about with an air of hesitation, of uncertainty. All this showed that the emergence of this species had probably begun on that day, so, judging by the last year's population, we had reason to expect that the next two days would show an exodus of great magnitude. Unfortunately, I could not be present during the next few days.

On June 13, a very different type of activity was apparent. Hundreds of turrets were already completed and hundreds of busy mothers were flying in and out of their nests. In two weeks wonders had occurred. The males had come and gone—not one was to be seen. Judging by the progress of the work each activity must have been practically simultaneous for the whole group. Thus, all nests were in the same stage of construction, indicating that the work had begun simultaneously; hence probably emergence and mating had occurred for all within a day or two.

The amount of work which they had already done was enormous, such as could only have been accomplished by their toiling as they do from sun to sun. At 5:30 a. m., one day I saw some of them beginning their work, and at 7:30 p. m., when it was almost too dark in the shadows to find their burrows, they came home and crept in. Later in the season they were not so industrious early and late on cool or cloudy days. It is their habit to carry water in the gullet, with which to reduce the hard yellow clay to workable mud. When one takes a bee in a test-tube, it disgorges the water on the glass in its futile fury. On one occasion, several bees in a test-tube disgorged so much water that they became quite drenched and made their elegant pubescence all sodden.

The notable feature was that this species had again increased enormously. Their distribution over the face of the clay bank was interesting: at the extreme south end were 10 turrets, in the central part, 275, and at the extreme north end, 390, making a total of 675 in three rather distinct groups. Besides this, more than a hundred bees had nests with no turrets and during the week I saw about 75 more chimneys constructed. This may indicate that each mother may make more than one nest in a season.* Many of the bees were bringing in pollen, others were building, and yet many more than three-fourths were at this time coming in apparently empty-handed. I think that they moisten the pollen with nectar, and this would mean many trips which to an observer would appear empty. Then again each cell is varnished inside to a certain depth which gives it a smooth glossy finish. This is no doubt for the purpose of making the brood cup impervious to water; at least when one drops water on the inside from a pipette, the drops retain their shape, and if the entire cup is filled, it retains the water for a long time. On the contrary, if a drop be placed on the outside of the cell, it immediately spreads and makes mud out of the mass. This varnish is probably made from plant resin that is carried at the time when they seem to be coming home empty handed. This bee, and the two other species of mining bee, do more than merely make a hole in the ground and fill one end with food; they actually make mud honey-cells which can be taken from the burrow in-

*There may be dull seasons, e. g. cold or dry, like 1917, when it would be impossible for a female to make more than one nest.

tact (Fig. 11), and all three species varnish the interior with the waterproof substance already referred to.

As noted above, they customarily work from early till late. On June 17, 1918, when the temperature* dropped from 98 degrees to 79 degrees Fahrenheit, their activities were greatly lessened. Less than a dozen assumed activity at all.

I tried to find where they got their pollen. On a persimmon tree some two hundred yards away, with its blossoms already deteriorating I found many bees, including this species, getting nectar. The two populations, bees and blossoms, waned at the same time. In 1921, notes on the relation of this species to the persimmon blossoms were made, and details are given elsewhere. What other sources of food supply they may have had I did not learn.

From May 28 to June 13 of the year 1920, they had built turrets to the enormous number of 675, a substantial increase over the number for the previous year. On July 21, only a week later, these short lived creatures were almost gone; only two live females could be found, the remnant of the recently noisy and mighty throng, and dead specimens of *A. abrupta* were scattered all about. In 1921, Man was again a factor in regulating the abundance of *Anthophora* life; the tenants of the "Ham and Bud" club-house unwittingly caused the death of hundreds of these little creatures, by merely going away and leaving the door of the screened porch open. The bees, in their circuitous flights, entered this open door at the head of the stairway (Fig. 8, point x), and were not able to find it again to make their way out; thus the screening which was intended to keep insects out,

*U. S. Meteorological Summary for June, 1918.

kept these in. Within the porch was a pitiful sight; in the two sunniest corners of the porch was literally a drift of dead bees. In their desperate attempts to escape, they had directed all their efforts against these two points of maximum sunlight, and even while I watched, at the southeast corner in the bright sun were one hundred and fifty mothers trying frantically to escape. It was with a feeling of satisfaction for the privilege of doing reparation for the wrongs done by my kind that I picked these up one by one, and liberated them.

It seems strange, and yet it is logical, that these creatures could not find their way out. In the first place they had entered by chance, instead of direct quest, which would entail flight of orientation and the formation of memory images of the open door. Second, these are sun-loving creatures, following the greatest intensity of light, so it is easy to see how this factor would guide them in their efforts to escape. This failing is common not alone to *Anthophora abrupta,* but to other insects as well; several specimens each of *Arotes amoenus,* Cress. (R. A. Cushman), *Megarhyssa lunatrix,* Fab. (R. A. Cushman), and *Tabanus lasiophthalmus,* Macq., were also found there. A humming-bird had been trapped in just the same way, and its little carcass too lay in the sunniest corner, with its delicate bill thrust through the wiring, showing its frantic efforts to escape.

An actual count of these dead bees gave me 18 males and 703 females. This, plus about 300 females then at work, shows the enormous proportions to which this population had grown. Furthermore there should be added to this total some 60 specimens from this group that had been lost in certain of my experiments. One wonders what would have happened to the bank in the following year if all these mothers, over 1000, had been left alive to propagate the proportionate population. It seems hardly possible that the clay bank could have held them (and we know that crowded housing conditions lead to ill health and ill morals). Would they, under such pressure, have disseminated over other areas?

At the end of the season the results of this catastrophe could be seen, for on June 24, 1921, we could count only 175 nests, as compared with the 675 counted for June 13, 1920.

The white-banded bee was now present, but in shamefully reduced numbers. One can hardly say that the *A. abrupta* in ever increasing numbers had simply crowded out the white-banded bees, because there was so much unusued space about the clay bank, and the two species occurred at different times, so they could not have been in competition for the same flowers. It was almost wholly a question of parasites, and this is treated elsewhere. Other details on the life history of this bee, and the relation of the species to moisture, light, etc., are given in later pages.*

White-banded Mining-bee, *Entechina taurea* Say [J. C. Crawford].**

The preceding pages show how the mining-bees, *Anthophora abrupta,* rose in five years from a colony of few individuals to a great and important population. We have also seen how *A. abrupta* emerges early in summer, does its life-work in about thirty days and is done

*In this paper I have given the ecological aspects of the life history of the insects. The more important species of bees and wasps will be treated biologically in other papers to follow. It is, however, often difficult to draw the line between the two aspects of the study.

**Mr. Rohwer writes that this bee is now known as (*Entechnia*) *Melitoma taurea* Say.

for that year. These pages will show that each year immediately after this, the second mining-bee, *Entechnia taurea,* comes upon the scene and continues the mining activities. The bees were observed for five years, and their numbers ran practically in inverse ratio to those of *A. abrupta;* as the one increased, the other decreased.

These white-banded bees (Fig. 7) emerged from the clay bank in 1917 on about July 16, and took up their work on the spot. This species likewise made turrets over its burrows, but they were a little smaller in size and of finer texture than those of *A. abrupta.* Like *A. abrupta,* these bees did not seal their burrows, either at the end of the chimney or the mouth of the burrow.*

The males of this species do not seem to emerge before the females; or at least, if they do, they do not die earlier, for on July 31 I saw a lot of frolicsome males segregated at the north end of the bank.

The activities of the white-banded bees continued throughout the summer. They never swerved from their self-restricted nesting areas, two spots at the extreme ends of the clay bank. By August 14, the burrows of these bees were becoming somewhat abundant, and the dancing males had now spread themselves to the south end, where they buzzed and danced about the busy females coming home heavily laden with pollen. While some of the latter burrowed horizontally into the face of the bank, others dug vertically into the flat top. They seem to have a preference for the top, since about ninety per cent of the nests were there. These bees, like their predecessors, also carried water to moisten the hard clay

*One occasionally finds the turrets sealed at the orifice, but in all the specimens of this kind which I examined, the burrows had been usurped and used by the wasp, *Trypoxylon clavatum.*

to make it workable; then they carried out mouthful after mouthful of soft mud in the form of pellets. These were used in the construction of the chimney until that was of adequate size, after which the surplus material was kicked aside.

By August 20 the males had disbanded and were no longer seen about the premises. They had not gone far, however, but were around on the other side of the house, resting, one each in the wild morning-glory blossoms which they had found there. They quietly occupied the floral cups for hours at a time, serving no good purpose that I could see, but only usurping the rightful place of the pollen-hunting mother, and often even fighting desperately to keep her out—a perfect dog-in-the-manger. At the end of August, despite several days of rain, females were still at work bringing in loads of pollen. By September 3, several cold nights had caused them to lay aside their virtue of early rising. They were abundant and actively engaged at this late date. By the 6th or 7th, however, only about a dozen bees were still alive, or at least in evidence about their business, some bringing in pollen and others actually excavating. On September 12, with the preceding night very cold, no bees were to be seen at work in the morning; at noon, one crept out, and by three o'clock, two more ventured. But even at this late date, eight males were seen as before, huddled in the cup of the morning-glory flowers, where they had spent the night. These flowers had not closed for the night,* and even at ten a. m., these males were in a tor-

*It is unusual for morning-glory flowers not to close at night, but this actually happened late in the season when the nights were cold and dewey. These flowers which remained open gave an excellent shelter to the bees.

pid, dejected condition, heavily covered with dew. On September 23 it was quite apparent that these insects were being rapidly reduced in numbers by death. Several dead ones were picked up from where they had fallen beneath the mouth of their burrows, and there was no way of ascertaining how many more dead remained within. It is natural to think that females of such species as this continue to work to the last, but on the occasion of my visit on October 3, there were three mother bees that were no longer exerting themselves on home cares, or in any way trying to work, but appeared to be simply idly waiting to be overtaken by death. Indeed they lingered on beyond their just day, for even their food-plants, the pollen bearing flowers, had almost all ceased to bloom.*

While I was unsuccessful in determining the number of nests made by each mother, the total number of nests for the whole colony from year to year is of interest. In 1917, there were 62 nests; in 1918, 55; in 1919 the number went down to 37, and in 1920, 49; in 1921, 51 and 1922, 40.

When one sees the enormous population of *Anthophora* in 1921, many of which were trapped and perished, and compares it with the 1921 *Entechnia* population, one sees a vast difference in their rate of increase; in the five years residence, one species has increased phenomenally, while the other has barely held its own.

The dates of emergence for the various years will be treated under climate, and other details are elsewhere given in these pages.

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*At even a later date than this, however, on October 17, 1919, one was seen to enter its burrow at Hematite, Mo., several miles south of the clay bank.

The Mining-bee, *Anthophora* (*Anthemöessa*) *raui.** [S. A. Rohwer].

In 1917 I noticed among the turrets of *Anthophora abrupta,* three which turned upwards, as indicated by arrows in Fig. 9. The next year, there were five of these in the mass, and, since this showed a very distinctive digression, I concluded that this might be an advantageous variation, and began forthwith to philosophize upon the laws of variation, heredity, and survival of the fittest, with the deepest solemnity. The reason why the reader is mercifully spared this is that, when making a later visit to the place, June 13 to 19, 1920, I was shocked to find about 90 of these upturned turrets, segregated into three distinct colonies, and bees, which greatly resembled *A. abrupta,* but still showed distinct differences, industriously taking care of them! In all characteristics excepting the upward turn, the turrets were precisely like those of *A. abrupta.* Since these bees had habits of digging, carrying water, and provisioning their nests with pollen, all of which were so very similar to the way of *A. abrupta,* it was not surprising that they proved to be taxonomically very nearly related to the latter species.**

Thus the great increase in the population in 1920 came practically as a saltation, for in 1918 they were practically nil. This sudden increase seems entirely possible, however, even though this species has the same short adult life cycle that *A. abrupta* has for I am of the opinion that this bee makes more than one nest in a

*Described in Proc. Ent. Soc. Wash. 25:100, 1923, by Mr. Rohwer, who writes that it is closely allied to *sodalis.*

**In 1922, this species appeared three days later than *A. abrupta,* and a few stragglers were seen a week after *A. abrupta* had all died off.

season, and has three or four cells to each nest. By the third week in July, the population was noticeably waning, and before the end of the month had almost disappeared.

When these bees make their turrets, they use a process which I have not yet been able fully to analyze. The bee walks out backward, and when the tip of the abdomen touches the rim of the chimney, she applies her pellet of mud. At first this is quite crumbly, but soon one sees that in some way water passes over it, making it more plastic and adhesive. One can see the water as it spreads over the mud, but cannot see where it comes from. It does not seem to come from out of the abdomen and if it comes from the mouth one cannot see how it is passed to the tip of the abdomen. One load of mud brought from within makes from one-fourth to one-third of a ring.

As mentioned before, the only perceptible differences between the chimneys of these bees and those of *A. abrupta*, are that these turn upward instead of projecting from the bank horizontally, and these are usually solid tubes while those of *A. abrupta* have a gap or fissure, of unknown significance, extending the full length of the tube on its upper side.* Sometimes this upward turning chimney goes into pretty curves, but it never fails to turn upward. This distinction is unusually short and clear for the two species; I have never yet seen an *A. abrupta* go into one of these vertical turrets, nor have I ever seen an *A. raui* enter the horizontal ones, although I have often seen both species go into holes that had no turrets.

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*Out of several hundred turrets of *A. abrupta*, only twelve lacked this split.

My earlier notes show that in 1917 there were only three of these upturning turrets, which indicated that this species was newly arrived then. As early as June 18, 1921, I counted 40 such turrets, with *A. raui* coming in and out. They were not scattered over the whole bank, but were distributed in groups; this probably means that the bees build very near to the spot where they are born. Fig. 10 shows a colony of 20 upturned turrets in a small area (for this picture a wad of cotton was placed in each vertical chimney, to better distinguish them from their neighbors), and Fig. 6 shows a mother twice natural size.

I accidently broke off the turret of one nest about an inch long, while it was in course of construction. The bee coming out with the next load of mud did not seem in the least surprised, but without turning about to examine the condition, she placed her load at the base and began on a new turret. On June 18th ten new turrets were just begun.

The following record of one typical bee's work gives an idea of the manner of making the turrets. This bee entered a shallow old hole and kicked out a small quantity of loose dust; after some minutes of this, she left and returned presumably with water. She then began to bring out loads of mud and started to make her turret. The face of the bank here was uneven and her first few loads went to fill the depression, first above the orifice and then below it, until it was level and ready to receive the chimney, which she continued in the same manner. A trip for water usually consumed two minutes. In leaving the nest for water she came out head first, having turned around in the tunnel; in coming out with mud, she always emerged backwards and applied her mortar. Between 11:10 and 2:30, the burrow was dug and the chimney built up to a height of ⅞ inch; from that time until five o'clock, nothing more was done.

Like *A. abrupta,* these bees build very definite cups of mud within the burrows, in which to oviposit. Fig. 11 shows a group of such cells—some of them opened to show the pupae within, while Fig. 12 shows the pupae in two stages of development. The interior wall of this mud cup is varnished with some substance which renders it waterproof, a condition we have already described for *A. abrupta.*

Halictus bee, *Halictus* (*Chloralictus*) *zephyrus* Sm. [J. C. Crawford].

A small burrow which went down vertically on the top of the bank first attracted my attention in 1917. It contained a pair of these *Halictus* bees. One of them, probably the male, closed the aperture of the burrow with his head, and prevented his consort from entering until it suited his whim to admit her. This was the only nest of this species found that year, and it now seems likely that in taking the pair for identification, I exterminated this species in this locality, for in the two years following none appeared.

The species must have been reinstated, however, because in 1920, three burrows were again discovered, and in 1921, a dozen nests were there. They dug their burrows horizontally into the face of the clay bank near the base. Below each burrow was a little mound of pulverized earth. It was at length discovered that several adults occupied one gallery, and the nesting cells branched off from either side of this gallery (Fig. 13).

Each of these cells, or pockets, contained an egg attached to a small pellet of yellow pollen.

At first I thought that it was always the head of the male which plugged the doorway; but as I later learned that each burrow was really an apartment-house occupied by many adults, I have been in doubt whether the one at the door may not have been one of the feminine occupants. This common passage way is larger underground than is the doorway, which is just wide enough to admit one bee at a time. One nest which I opened had a tunnel in the hard yellow clay nine inches long and three-sixteenths of an inch wide, excepting at the narrow entrance. Pockets on either side of this tunnel had young in all stages of development, from minute creatures clinging to a little ball of pollen, to pupae already deeply pigmented. Besides these there were a half-dozen adults, possibly mothers or adult sisters. After the nest had been dug up, eight bees returning home congregated before the ruins. The adults as they emerge nidify in the same tunnel and gradually extend it. While these are solitary bees they are very neighborly, and this habit of community dwellings seems to point in the direction of socialization. Indeed it almost seems to be a link between the solitary and the social habit of bees.

Near the end of the season, October 2, 1920, and again September 28, 1922, at Wickes, Mo., I witnessed a new phase in the life of this species. Thousands of these little bees were executing a sun-dance on the sunny hilltop, where the grass was closely mowed. They were in a great many groups of a few bees to several hundred, while a few groups had several thousand. Some groups were close together and some isolated, some dancing over the short grass and others over the barren clay spots. Thousands were taken in the net, but most of them escaped through the large mesh. They kept near to the ground and moved rapidly; they were so small that individuals could not be followed. Some burrows in the grass were plugged with the heads of the guards and in some the females were seen to enter. From the size of those in the dance, I suspected them to be males, and the behavior indicated courtship.

Little Carpenter-bee, *Ceratina calcarata* Rob. [J. C. Crawford].

A good many stems of the red rambler roses had been cut back, and each year dozens of these contained nests of these bees and their parasites, but in so far as I could see there was no relation between these bees and the other inhabitants of the clay bank. They went afar for their pollen, and neither preyed upon the others, nor were preyed upon; in fact, in every way they held themselves aloof from their neighbors.

The caterpillar wasp, *Ancistrocerus fulvipes* Saussure.

Among the pioneers in the clay bank should be considered the caterpillar huntress, *Ancistrocerus fulvipes,* since she almost never used the old burrows for nesting, but dug her own tunnels among those of the mining bees.

In 1917, this species was seen about the clay bank as early as June 17, when three adults were out. By July 7, this number had increased to a dozen, and by the 16th, neither their number nor their industry had waned, although by this time, their companions *Anthophora abrupta, Trypoxylon clavatum* and the chalcid parasite *Monodontomerus* had disappeared, either temporarily or permanently for the year according to species. For several days these mothers had been digging, carrying mud or bringing in caterpillars. On July 30 I returned after a few days absence and found the numbers of this wasp materially reduced, so I suspected that this was about the time for the passing away of the first generation. Thereafter, a careful watch up to August 10 revealed no trace of this citizen of the colony. On August 14, one wasp, probably the first of the second generation, was found at work. Up to August 20, this one and another were the sole representatives of their tribe, and on August 30, three were out. Although September 3 and 4 were almost sunless, yet 7 individuals were active; this was the maximum number of the second generation seen at any one time; from September 6 to 23, only two or three at a time were out at work. On the last visit of the year, on October 3, the day was gray and chill, but it found two of these mothers still at work, one plugging her burrow with mud and the other bringing in caterpillars, both plodding faithfully on toward the completion of their work, oblivious to the fact that it was now only a matter of days or perhaps hours until for them the sun would shine no more.

In 1918 this wasp, like the other species described above, emerged and began its work much earlier than in 1917; on May 28, they were already out and busy. In 1919, no records were made of their emergence, but in 1920, when the bank was visited on May 27, they were again found at work. Their appearance is correlated with temperature conditions in later pages. They appeared in slightly greater numbers in 1918 than in 1917. On July 17, about the same number were at work; on July 31, none at all; hence this is evidently approximately the dividing line between the two generations. A visit just a month later showed a partial return of the population.

No notes were made for 1919. In 1920, as already stated, May 27, found these wasps already alive. Their activity continued throughout June and the most of July. I was unable to visit the grounds then, at the date when the depletion of the first generation was expected, but on September 2, *A. fulvipes* were more abundant than ever; 13 individuals were seen at one time, the greatest number yet seen at work simultaneously, which indicated that they were on the increase. None were in evidence on October 3.

These notes, while not based on large numbers, are probably sufficient to show an increase in numbers, an earlier date of emerging when the weather is warmer as with the other inhabitants of the bank, and a strong indication of two generations a year.

These wasps, like the mining bees, went elsewhere than the bank for the food for their young and themselves; hence the relation that this species had to the community as a whole was in bequeathing their discarded tunnels to the other inhabitants who might want them, and in occasionally falling prey to other insects. One such instance was observed on June 28, 1920, when a bug, *Reduvius personatus* L. (W. L. McAtee), which was amply protected in coloration by having its sticky body covered with dust, and which was half concealed in a crevice, was found feeding upon this wasp.

This eumenid was elsewhere seen to nest in tunnels in logs; for an account of its life history, see "Wasp Studies Afield."

The caterpillar wasp, *Ancistrocerus unifasciatus* Sauss. [S. A. Rohwer].

Three mothers of this species were seen carrying green caterpillars into cracks of the old building above the clay bank, on May 28, 1921, where they were evidently nidifying in the old mud nests of *Sceliphron caementarium*. I have previously recorded* the fact that they use the old cells of this mud-dauber.

The spider-wasp, *Episyron biguttatus* Fab. [S. A. Rohwer].

This Pompilid wasp was seen kicking dirt into a small burrow at the base of the clay bank. She would quickly sweep in the earth with her front legs and then with rapid beats of the tip of the abdomen she would pound it down. The wasp was taken and the burrow opened; one-half inch below the surface we found a perfectly round cell of the size of a pea, which contained a spider with an egg cemented to the dorsal side of the abdomen.

The pipe-organ wasp, *Trypoxylon politum* Say.**

This wasp should probably be included among the inhabitants, since three large pipe-organ nests were were built on boards or joists of the porch over the bank, but a more logical and interesting reason for including it was that several of these mothers were seen foraging for spiders which made their homes in the old bee burrows. Thus the species which seemed almost an outsider could affect the life of the community even though in a small way, by reducing the number of spider

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*Ent. News 24:396, 1913.
**Formerly called T. albitarse.

occupants which in turn would have reduced the number of bees and parasites. One nest gave forth its adults between June 26 and 29, 1917.

The mud wasp, *Sceliphron caementarium* Drury.

This mud-dauber stands in the same relation to the life of the unit as does the pipe-organ wasp, just mentioned. These yellow-legged wasps, too, plastered their mud huts on the wooden porch overhead, and in one instance even attached one direct to the clay bank, in a depression which I had made in digging out a nest; a crooked, lop-sided, distorted piece of work it was, and it could not have been different in the cramped corner, but with yards of flat surface overhead, why should a sensible wasp choose a spot of this kind!

Like the *Trypoxylon politum,* these wasps were occasionally seen entering the burrows in quest of spiders. Their discarded nests about this unit were utilized as homes by *Trypoxylon clavatum, Ancistrocerus unifasciatus,* and *Pseudagenia mellipes* and the burglar wasp *Chalybion caeruleum* made the best of the opportunity to break into them in a most desperate way.

The Larrid wasp, *Tachysphex terminatus* Smith.

These little wasps appeared about July 16, 1917. They were digging their burrows in the loose dirt on the top of the clay bank and provisioning their nests with short-horned grasshopper nymphs. Toward the end of the month their numbers became much reduced; on July 30, only three females were in evidence.

These wasps are supposed to be essentially sand-loving, but here we found them digging in the loose dirt on top of the hard clay bank, and as a consequence the nests were very shallow, so shallow, in fact, that the prey could be exposed to view by merely blowing the dust away, whereas those burrows found in sandy areas had a much more substantial depth.

On August 10, I found that the number nesting had increased to six, which would suggest, though not prove, a second generation. Also it became evident at that time that this wasp sometimes falls prey to the other inhabitants; one dead specimen was taken from the web of a spider occupant of the bank. Only four days later I found these Larrids had suddenly increased to about thirty, with a goodly proportion of males in the lot. Excited courtship and mating were the program of the day. The males outnumbered the females, and the usual fight for partners occurred, three or four males sometimes struggling together for the possession of a female. Even during this commotion, however, about ten females managed to attend to home duties, between interruptions, bringing in locust nymphs mostly of the species *Chortophaga viridifasciata* De G. (A. N. Caudell) (Fig. 14). Toward the end of August the number of mothers began to diminish; on September 3, one was found dead in its doorway; this probably indicated the approach of the season of natural death. And so it was, for only one or two were seen after that, and on my farewell visit for the year, Oct. 3, none of these sun-loving creatures were found to have survived the cold, gloomy days just preceding. The wasps have never appeared in early spring, and a few cocoons taken from the bank on April 28, 1921, gave forth adults on June 2; this indicates that this is a summer and fall creature.

In 1918 these wasps appeared in slightly greater numbers than in 1917; by 1920, the population had trebled. Just why this habitually sand-digging Larrid should choose to adopt itself to the yellow clay of the bank, and why after this change, it should flourish and increase in numbers, is still an unanswered question.

We see only slight relation between this wasp and the other inhabitants of the clay bank, since these mothers must go abroad for the Orthopterous prey; hence probably it had nothing in common with its neighbors other than occasionally falling prey to the spiders there.

The devil's horse, *Stagmomantis carolina* Linn.

The egg-cases of the devil's horse were often found plastered to the boards above the bank, and each June the little nymphs could be seen walking about the bank. They are carnivorous, and probably fed upon some of the very small insects about the bank, until they in turn fell prey to spiders that were occupying the old burrows.

The paper wasp, *Polistes pallipes* Lepeletier.

During the four years there were probably a dozen nests of *P. pallipes* on the under side of the porch and attached to the rose bushes in front of the bank; but in so far as I could see, the wasps had no relation to the unit as a whole, since they made their own nests, and did not get prey from the clay-bank; neither did they fall prey to the inhabitants. Sometimes, they built their nest in narrow spaces between boards, which resulted in nests strangely shaped, but the point which remained most puzzling was that every year some should persist in building in this cramped space between two joists, and making these unusual nests, when there were hundreds of square feet of clear ceiling and wall space ready to accommodate them.

The stick-bug, *Emesa brevipennis* Say [W. L. McAtee].

Another insect which should be classified as a pioneer in the unit, even though it makes no nest, is the stick-bug, *Emesa brevipennis*. It spent its whole life among the rubbish, boards, etc., piled on top of the bank. The nymphs were seen as early as July 16, and the adults as late as October 12. During their immature stages they were inconspicuous, hence not frequently noticed, but when full grown and more easily noticeable, they were observed in great numbers. Since they are carnivorous in habit, they were probably very directly responsible for some changes in the population of the unit. While I have never chanced to see them actually prey upon the inhabitants of the bank, I have seen them feeding upon insects which had been visiting the bank for shelter. One was imbibing the juices of an adult moth, *Pyralis cuprealis* Hubn. (H. G. Dyar); another was seen to hold an immature (second stage) short-horned locust in the fore-legs, mantis-fashion, and, with its beak inserted, imbibe its juices for a whole day. Whether they actually captured sleepy bees and wasps, I cannot say.

Ants. *Crematogaster lineolata* Say [W. M. Wheeler].

A crack in the porch post was the home of a large colony of these ants. Its part in the game of give and take being played on this scene was to supply food to the ant-lion larvae, whose pits were in the dust at the base of the bank. The spider, *Habrocestum pulex*, and also an unidentified ant-mimicking spider were observed feeding upon them. These ants often covered up the cracks in their posts with a gummy secretion. On August 14, 1917, many winged specimens were in the lot. This colony remained a permanent part of the population during the five years observation.

On my spring trip afield, April 2, 1921, I found on the ground about 400 of these ants, dead. They were still soft; hence they could not have been dead long. Moreover, they had not been there on February 26, when I examined the bank. I had previously noted these ants hiding in the cracks in these walls and plugging the crevices with a gum-like substance; hence they could not have merely fallen out. The question remains whether these had come out to meet the spring and had been caught by a severe frost, or whether they were the accumulated dead of the winter, which had been dumped out by the survivors.

In another instance, when a *Polistes pallipes* queen was taken from the nest above the bank for use in homing experiments, a colony of these ants discovered the nest soon after it was left unguarded; they bit into the walls of the cells and completely removed the larvae bit by bit. This task consumed two days, during which time the nest was black with ants.

Anti-lion larvae, *Myrmeleon immaculatus* De Geer [A. N. Caudell]. *Myrmeleon mobilis* Hagen [A. N. Caudell].

The numerous insects mining in the bank kicked out quantities of finely pulverized clay, which accumulated at the foot of the bank (Fig. 1, X). This made an excellent abode for the ant-lion larvae, which dug their pits of various dimensions (Fig. 15) and fell heir to occasional bits of provender brought in for the other nests but dropped, as well as sometimes the spider or ant inhabitants themselves or occasional visitors to the settlement. That this was a favorable place for them to flourish and multiply was evidenced by the fact that in 1917, 20 pits were counted at the foot of the bank; in 1918, 150 were there, but most of these were gathered to send to a friend for study. Hence in the following years they appeared again in about the same numbers as in 1917, at the base and also on top of the bank. Of course we should bear in mind that the ant-lions, by virtue of their peculiar mode of development, are well prepared to survive and flourish, so that, like the poor, we shall have them always with us. They neither perish nor migrate if food becomes scarce for a time, but they simply lie dormant, and put off growing and transforming for a year or so until food again becomes plentiful.

Thus, an examination on October 13 revealed many ant-lions in all stages of development; some were reconstructing their pits in my presence, others were larvae in all sizes from small to large, with pits in proportionately varying sizes. Precisely these conditions were found at all other seasons, from the opening of spring to the close of autumn. This shows that they have no set time of the year for their metamorphosis, but change whenever they have reached a certain stage, regardless of the time of the year. Some that were brought into the house and fed abundantly on flies grew rapidly, pupated in a few days and emerged as adults from three to four weeks later.

One must not forget to consider the life habits in relation to the environment, when contrasting the development of the ant-lions with that of the bees. The larvae of the bees are supplied with sufficient food to carry them through their development without their exertion, while the ant-lion larvae must get what they can. With the ant-lions, it is either a feast or a famine—when food is plentiful, they develop to maturity quickly; when it is scarce, they do not die, but combat famine with patience. Herein Mother Nature anticipated Victor Hugo, who said: "A clock does not stop short at the precise moment when the key is lost!"

An interesting detail in their method of feeding was noticed when a *Grapta* caterpillar was dropped into one of the pits. The ant-lion captured it and promptly sucked out the juices; five minutes later it was discovered that the ant-lion had also snipped the body-wall and was dragging the viscera out through the aperture.

The only relation these larvae had to the other inhabitants of the unit, was to eat any insects, such as weevils and caterpillars, which, through accident or misfortune, fell into their pits. I noticed also that occasionally their pits served as good starting points for the burrows of the Larrid wasp, *Tachysphex terminatus.* The *Anthophora* bees were probably too big game for them, but I did find one struggling with a dead bee in the pit. Whether the dead bee had fallen into the pit, or the ant-lion had actually attacked and killed a live one which came within its reach, I do not know.

One ant-lion passed five weeks in the pupal stage; having spun the cocoon on April 16, 1921, it emerged as adult on May 24. A second one spent six weeks in that stage, or from April 6 to May 25, 1921.

House-Spider, *Theridion tepidariorum* Koch [J. H. Emerton].

These house-spiders should be reckoned as among the original inhabitants of the unit, since their webs were occasionally found about the porch above the bank. Their actual activity was observed only once, on October 12, when one was intermittently feeding upon a large, hairy caterpillar caught in its web. I feel confident, however, that, since they are night prowlers, they participated more fully in the life of the community. Elsewhere I have found this species feeding upon a wasp (*Odynerus anormis* Say).

Résumé of Pioneers.

To summarize, then, the five years' work at the clay bank gave us as pioneers, those which actually opened the way for others, the eighteen species listed below. It is interesting to note that six of this number were solitary bees, seven were wasps, and the remaining five belonged to as many different orders.

Carpenter bee.	*Xylocopa virginica.*
Mining bee.	*Anthophora abrupta.*
Mining bee.	*Entechnia taurea.*
Mining bee.	*Anthophora raui.*
Halictus bee.	*Halictus zephyrus.*
Small carpenter bee.	*Ceratina calcarata.*
Mining wasp.	*Ancistrocerus fulvipes.*
Eumenid wasp.	*Ancistrocerus unifasciatus.*
Spider wasp.	*Episyron biguttatus.*
Pipe-organ dauber.	*Trypoxylon politum.*
Mud-dauber.	*Sceliphron caementarium.*
Larrid-wasp.	*Tachysphex terminatus.*
Paper wasp.	*Polistes pallipes.*
Devils horse.	*Stagmomantis carolina.*
Stick-bug.	*Emesa brevipennis.*
Ant.	*Crematogaster lineolata.*

Ant-lion larvae.	*Myrmeleon mobilis.* & *M. immaculatus.*
House spider.	*Theridion tepidariorum.*

(c) Renters.

In this chapter are enumerated the secondary inhabitants of the old clay bank, those which came as tenants of the burrows made by some of the creatures listed in the foregoing chapter. These, for the most part, were less hardy than the pioneers; they came into the community, evidently quite willing to utilize its advantages and share its comforts. Often they dropped in merely for shelter or food, and remained to the end of their days. These renters, besides using the old dwellings, influenced the population of the unit in two ways —by using the other inhabitants for food, and often by being eaten by them.

The Pompilid wasp, *Pseudagenia mellipes* Say.

This wasp was occasionally seen about the clay bank. There were four in 1917 and perhaps a dozen in 1920. In "Wasp Studies Afield" we have told how this creature nests in both new and secondhand domiciles; sometimes she makes small mud nests under loose bark (one such nest was found inside an oak-apple lying on the ground), and at other times she modifies the nests of the mud-daubers to suit her needs.

The interest of *P. mellipes* in the bank was the prey which it sought there. The wasps were often seen going into the old bee-burrows, now occupied by spiders, probably in search of food for their young. On a few occasions, they were seen going elsewhere for prey and bringing home their booty. The legless spider brought in by one of these *P. mellipes* was identified as *Pisaurina undata* Htz. [C. L. Shoemaker] and on another occasion a mother was seen at the base of the bank carrying a half-grown *Phidippus* spider. This versatile little wasp found in the old bee-holes both home and hunting-ground; she was actually seen to drag a spider up out of one burrow—its lair—and down again into another hole near by—her own nest. Thus we see this citizen finding in the clay bank "all the comforts of home," shelter or a domicile already provided, and food supplies available near her door, and she has just as little work to acquire the one as to get the other, whereas in the usual condition, the home-makers get the benefits of one or the other, but seldom of both. These wasps continue their activity throughout a fairly long season, from the last of May to the first of September.

Since they made their own mud cells in the old bee burrows, they are classified with the renters, although they had just as much claim to be among the pioneers.

Trypoxylon plesium Roh.* [S. A. Rohwer].

Only one specimen was seen here, and it was taken at the clay bank on July 7, 1917. I saw this wasp actually walk over two distinct spider webs without becoming in the slightest way entangled; evidently it was on a spider-hunt when captured.

*Mr. S. A. Rowher describes the species (Proc. U. S. Nat. Mus., 57:229, 1920) from this specimen and another which was seen to enter and leave a burrow in a fallen log at Moselle, Mo., on July 3, 1917. This one evidently had its nest there, but it was impossible at the time for me to dig it out. Moselle is forty miles west of the clay bank locality.

Trypoxylon clavatum Say. [S. A. Rohwer].

This species of wasp in which the male parent guards the nest while the female hunts, has been recorded as making use of old beetle burrows in logs, and cleaning out and using the old cells of the mud-dauber wasps. In the clay blank, they were quite abundant, here using the empty bee burrows, partitioning them with mud and filling each compartment with spiders.

When this species first made its appearance in 1917, about June 28, there were only three nests, each with its male guarding the doorway, and four days later there were seven. By the time of the next visit, on July 16, these had vanished, and for two weeks not a single *T. clavatum* was to be found. On July 31, the first one of the second generation appeared. Time dragged on and this one continued to be the sole representative of the species. Not until the first of September did others appear, and during that week a half-dozen or more were at work. During the latter half of that month, they succumbed to the inevitable. While *T. clavatum* appeared in the following years, their numbers became fewer; the species was not holding its own. No doubt one very considerable factor in the reduction of their numbers was the destruction I wrought in digging up their nests when their colony was not yet strong, in order to study their prey.

The relation of these insects to the unit was primarily in using the old burrows; with the male on guard in each nest it is not likely that the young of this wasp serves as host to any parasites. A comparison of the contents of their nests with the list of spider inhabitants of the clay bank shows that they must have gone afield for their prey. These details of the life history will be presented in a later publication.

Trypoxylon albopilosum Fox [S. A. Rohwer].

This wasp, with habits similar to those of *T. clavatum,* likewise occupied the old burrows of the mining bees. It was first observed on June 28, 1917, when several mothers were at work. They always appeared only in such small numbers, however, that I could not accurately define any seasons or generations for them, only that they were to be seen occasionally until early September. Since I opened part of the nests to study the contents, it was only natural that their population dwindled away, until in 1920 one lone survivor was observed. The relation of this species to their neighbors was the same as that of *T. clavatum.*

The Monobia mud-wasp, *Monobia quadridens.* Linnaeus.

This wasp, commonly called the carpenter mud-wasp, but, according to our account in "Wasp Studies Afield" not a carpenter at all, can be regarded as only a secondary inhabitant of the clay bank, since it made no nest of its own, but occupied that of the carpenter-bee, *Xylocopa virginica.* These wasps were seen each year bringing in mud for partitions and caterpillars for food for their young. On one occasion, as previously recorded, one *Monobia* mother actually utilized the tunnel of a mining-bee, carrying in caterpillars and sealing up the opening with mud.

This wasp appeared from year to year in very limited numbers, not more than 6 or 8 being present at work at any one time, and most of the time not even that many. Since the shedding-skins of the silver-winged parasite, *A. tigrina,* were often to be seen adhering to the wood near the holes, it seemed probable that *Monobia* suffered its share of the ravages of this pest.

Their season was long; the first appeared about June 26th, 1917, and on October 3, two were seen, still clinging to the woodwork over the bank, stunned and half dead with the cold, while a third one was seen to enter its tunnel. In 1918, they appeared in decreased numbers, and by 1920, only three could be found. I suspected that *A. tigrina* was more responsible than any other factor for their elimination.

The grass-carrying wasp, *Chlorion* (*Isodontia*) *auripes* Fernald. [S. A. Rohwer].

This wasp, a very conspicuous if not numerous member of the unit, occupied the old tunnels of the carpenter bee, and occasionally she used the old burrows which had been made in the clay bank by the mining bees. It is very easy to tell just where this wasp mother has her nest, for instead of plugging the opening with mud or otherwise concealing it, she stuffs the aperture with grass, drawing each strand in by its middle, so that a broom-like tuft protrudes prominently, thus revealing at once to an experienced eye the location of her nest.

This insect occurred in very modest numbers; no more than three or four individuals were at work at any one time. In 1920, neither the wasps nor their nests were to be found there. There was evidence to lead us to think that the silver-winged parasite had played havoc with these wasps, the same as with the other occupants of the carpenter bee galleries.

While these wasps, as well as the Monobia mud wasp, were to be regarded as secondary occupants of the carpenter-bees' burrows, the relationship was more complex, since by occupying these burrows they took just that much space from the carpenter-bee, because each generation of *Xylocopa* used the old domiciles, in so far as they were adequate, and if the tunnels had been usurped by other species, the mother carpenter-bees were obliged to spend their time and energy at the slow process of hewing wood instead of being fruitful and replenishing the earth. Therefore, the only direct bearing that these two wasp occupants had on the inter-relations of life in the unit as a whole, was to deprive the carpenter-bee of some of her rightful nesting-places and to serve as a host for the parasite, *Argyromoeba tigrina*, for they both gathered their food elsewhere.

The blue mud wasp, *Chalybion caeruleum* Linnaeus.

This wasp was heretofore regarded as the mud-dauber wasp making nests very similar to those of the "yellow-legs." On the contrary, I have shown elsewhere that this wasp does not make nests of her own, but occupies the nests of *Sceliphron caementarium*, either by breaking into a "live" cell and destroying the prey or by using the abandoned cells. In so far as the bank was concerned, however, this species was occasionally seen foraging for spiders among the burrows. On several occasions when one was foraging among the spider webs, she broke through or became entangled, whereupon, in a very skillful manner, she quickly disentangled the web from her person. Elsewhere, however, I have often found dead specimens that had been caught in spiders' webs.

These wasps were found to be present at the bank in great numbers on May 27th and 28th. This was before their nesting activities had begun. The significance of their presence has not yet been determined, so I could only state the circumstances. They were on an elm sprout six feet tall, which grew between the rambler rose and the front of the bank. Other insects were there too, so I thought possibly the aphids, which were plentiful there, constituted the attraction, but I could not see that they got anything from the aphids; in fact, the plant-lice were on the under side of the leaves while the wasps always walked about on the tops of them.

The wasps were constantly active on the shrub, flying and hopping about, running nervously over the foliage and jumping or dropping from leaf to leaf. The performance began at about 7:30 a. m. when the first few arrived and became active; the number rapidly increased as time passed. Standing a short distance away, one could see others coming in from various directions to join the dance—for apparently this gathering was some sort of social function—a stag affair, however, for a dozen or so taken in the net proved to be all males. I suspect that they were awaiting the emergence of their mates, and that if I had been on hand at the proper time, a little later, I could have witnessed some pretty courtship festivities.

Leaf-cutter bee, *Megachile campanulae* Rob. [J. C. Crawford].

One specimen of this bee was seen at the clay bank; it was at once taken for identification, and therein the prospective founder of a colony was evidently destroyed, since in the following years this bee was not seen again.

It was on July 30 that this individual entered one of the burrows. When this hole was opened, a quantity of the resinous material was discovered, but I had no way of knowing whether this or another insect had done the storing. The *Megachile* bees are leaf-cutters, and make nests in hollow stems, but I have elsewhere* recorded that they have been known to make their leafy cups in sheltered places as under clods of earth. Some bees gather resinous substances, but the *Megachiles* are not known to do so.

Another Megachile bee, *M. generosa* was taken while at rest on the bank June 3, 1921, but it is unlikely that its presence there was anything but accidental.

The Osmia bee, *Osmia lignaria* Say. [S. A. Rohwer].

This little bee did not appear in the community until 1920. In earlier researches I have found that this species builds its nests in mud nests of *Sceliphron caementarium.* Since these bees could not offer the excuse of foraging as an explanation for their presence here, I at once suspected that they were replastering the old burrows of the other bees here for their own nests in the same way that they utilize the old mud-daubers' cells. This I soon found to be true. About a half-dozen of them were seen thus occupied about the bank from May 28 to June 19, 1920, and a month earlier in 1921. They were also observed gathering pollen from the blackberry blossoms near by.

Spider, *Ariadna bicolor* Htz. [C. L. Shoemaker].

Of spiders, this was the most abundant species among the inhabitants of the clay bank, and from the first of

*Trans, Acad. St. Louis, 24:1-71, 1922.

September until frost their webs became more and more conspicuous. They made funnel-shaped webs, with the points of the funnels extending deep into the old bee burrows, and got a good living from the small fry that became entangled in the webs, such as visiting snout-beetles, ants, chalcids, flies, etc. I was surprised to find this spider actually feeding upon the bug, *Reduvius personatus* Linn. [W. L. McAtee]. Occasionally, however, the spiders themselves fell prey to some predatory wasp.

Spider, *Steatoda borealis* [J. H. Emerton].

Among the most important renters of the old burrows in the bank were the spiders, *Steatoda borealis.* They made light, irregular snares about the bank, more often about the old burrows, where many of the smaller insects became their prey. I have often seen *Chalcid* parasites and ants, *Crematogaster lineolata,* entrapped in their snares. The species may rightly be regarded as an inhabitant of the bank, either a renter or a pioneer.

They were very numerous in 1917, and only moderately so in the following years. They were as abundant as ever even so late as October 3, when one spider was making several brave attempts to subdue a large locust, *Tettigidae lateralis* var. *polymorpha* Burm. (A. N. Caudell), which was entrapped in its web. Two unidentified beetles were also their victims that day.

Résumé of Renters.

The following table summarizes the renters in this social group. They number eleven species, of which seven are wasps, two are bees, and two are spiders. All of these utilized to good advantage the burrows or the nests left by the pioneers, and they in turn left many of their burrows for a third tenant. Among these renters one might also include the bees *Anthophora abrupta*, because they sometimes used their old burrows for a second season, after enlarging and renovating them.

Renters of Old Burrows.

Pompilid wasp,	*Pseudagenia mellipes.*
Spider wasp,	*Trypoxylon plesium.*
Spider wasp,	*Trypoxylon clavatum.*
Spider wasp,	*Trypoxylon albopilosum.*
Monobia mud-wasp,	*Monobia quadridens.*
Grass-carrier wasp,	*Chlorion auripes.*
Cow-bird wasp,	*Chalybion caeruleum.*
Leaf-cutter bee,	*Megachile campanulae.*
Osmia bee,	*Osmia lignaria.*
Spider,	*Ariadna bicolor.*
Spider,	*Steatoda borealis.*

(d) Visitors.

This is a list of insects and larger animals which came into the community quite by accident, or in quest of food or shelter. In some cases they remained as permanent additions to the group, but in most cases, their stay was temporary. Many of them influenced the lives of the pioneers and the renters in one of two ways: either by using them as food, or by giving themselves as food.

Whether the word visitor or transients would be the better term to apply to this group is uncertain. Many insects alighted on the bank quite accidentally; others came there for the definite purpose of securing prey;

some which came as visitors remained at the bank to nest. It is this latter group which prevents one from definitely drawing the line between visitors and residents; the parents of all the occupants must at one time have been visitors, but not all visitors were occupants.

Reptiles.

On October 3 I noted a snake (Fig. 16) at the base of the bank, with a small portion of its body still within the rodent burrow, which I suspected was its home. It lay all day long in one position, as figured, but escaped when I attempted to capture it. At that season of the year, with food scarce, it probably had to wait a long time for a morsel, but if this creature had its home at the base of the clay bank all summer, it was no doubt a considerable factor in the control of the insect population during the season.

Common lizards or swifts.

During the entire summer of 1917 several common gray lizards made their home among the piled wood on top of the bank, and were undoubtedly a factor in reducing the life of the group. They, too, had enemies, probably larger ones, which I was unable to discover, and these all attacked the lizards in the same way, in the cases observed. During the summer, three dying lizards were found there at different times, all with torn abdomens and entrails protruding, as shown in Fig. 17. They were always found in the early morning hours, which indicated that the attack had been made during the dark hours of the night.

It was strange that these gray lizards did not appear the following season, although they were abundant along the railroad tracks less than two hundred yards away, but instead the blue-tailed lizard or skink appeared in their place. The blue-tailed lizard had evidently supplanted its predecessor, but since its habits are the same, very probably its function among and relation to the inhabitants and visitors at the bank were practically the same. This idea was strengthened when on three mornings in early June, 1922, a third species *Cnemidophorus sexlineatus* [D. M. Cockran], was seen coming out of a burrow and calmly making the rounds of the clay bank, often entering the bee burrows. It would enter head first, with the tail protruding, and often it would perform the quaint feat of, twisting its tail about the turret while its body was inside the tunnel. It seemed to find the burrows adequately roomy, for it would enter head first and also emerge head first. What it got out of the burrows I do not know, but since this lizard was seen to snap at *Anthophora* bees in the open, I suppose many of these bees were eaten within the burrows. The *Chalcid* parasites were also in abundance, and wild roaches were often seen in the burrows. The red-eyed flies, *Ganperdea apivora,* were numerous at just that time, and the skinks were seen successfully capturing these, and a few undetermined insects, in the open.

Toads.

In 1920 a big toad was a familiar figure about the bank. Before the end of the season, he had the portly figure of a war-time profiteer, and we felt justified in suspecting that the rest of the population had suffered accordingly.

Phoebe bird.

Among the vertebrates which were at home at the clay bank was a phoebe bird and her annual family. The nest, on one of the posts, was removed each winter, and each spring a new nest appeared in the same place. One year I noted two broods of young in the nest. Whenever I was at work at the clay bank, the mother bird went afar for her food, but often when I came suddenly upon the scene, I saw her quickly fly away from among the old lumber on top of the bank. From this I suspected that she lost no opportunity to get her insect food near at hand when she was not disturbed.

Red bird.

A red bird nested in the rambler bushes in front of the bank, during the summer of 1920, but in so far as I could see had no influence on the insect colony.

Ground mole.

There were a few rodent tunnels under the ground at the foot of the bank, and one year there were two distinct openings, but whether the moles or field mice affected the insect life of the bank I cannot say.

Man.

The human inhabitants of the dwelling whose porch covered the bank were not in the least a factor modifying this unit; further than the first construction of the site, no relationship existed. The house was almost always vacant except at week-ends, and even then none of this biped fauna came near enough to the bank to influence the life, since they mistook the inhabitants for bumblebees, and hence kept at a discreet and respectful distance. However, one man was a factor to be reckoned with in considering the enemies of the unit—that was the observer. That he should rightly be considered as a non-resident part of this ecological unit is evidenced by the fact that, in taking specimens for identification, he disrupted the fine balance of nature, but actually no more so than if he had been a lizard and captured these insects for food. He took only those species which were unknown to him, and then took them in minimum numbers. However, in some cases he was guilty of swinging the balance to some point where, without his interference, it would not have stood. Had he not taken the only *Halictus*, *Megachile* and others, these insects probably would have become established in the bank and their progeny would have done their part to modify the life of the community. The reader can easily estimate the extent of these depredations by glancing over the list of the inhabitants and noting all the species that have been submitted to experts for identification. I do not want to exaggerate this point absurdly, but I think it is well that we should realize that man is not a thing apart from the other factors in the balance of nature, but that he is only one species among many in the great game of give and take which makes up ecology.

Lepidoptera.

Pyralis cuprealis Hubn. [H. G. Dyar]. This visitor was found in the beak of a stick-bug, *Emesa brevipennis*, on July 16, 1917.

Two caterpillars belonging to the *Pyralididae*. [S. B. Fracker] were found promenading on the bank on September 12, 1917, and later in the day a dead one was taken from an ant-lion's pit. Thus, even though they came to the place quite casually, they served the community.

Pseudaglossa lubricalis G. [H. G. Dyar]. One specimen was picked up dead at the bank on September 3, 1917.

A caterpillar belonging to the *Noctuidae* [S. B. Fracker] was feeding on a small plant growing at the base of the bank.

Catocala innubens Guen. [Ernst Schwarz]. During the latter part of July, 1918, several of these moths sought daytime shelter here.

Herculia olinalis Guen. [H. G. Dyar]. The caterpillar of this moth was found walking on the clay bank on April 28. On the next day it spun its silken cocoon and emerged as an adult on May 22.

Hymenoptera.

Pompiloides sp. [S. A. Rohwer]. This wasp was foraging for spiders in the old bee tunnels during August and early September, 1917.

Arachnophoctonus ferrugineus Say. One specimen foraging for spiders on July 30, 1917.

Pompiloides americanus Beauv. [S. A. Rohwer]. This had come to the bank as a visitor on a foraging expedition, but had become a victim to the prey which she was pursuing and her lifeless remains were removed from a spider web on July 30, 1917.

Tachytes peptictus Say. [S. A. Rohwer]. On July 21, 1920, two or three of these green-eyed wasps were at rest on the vegetation at the edge of the bank.

Silaon sp. (S. A. Rohwer) one was nervously walking about the clay bank on July 30.

Sphex (*Ammophila*) *nigricans* Dahl. [S. A. Rohwer]. This was seen walking about the clay bank, August 14, 1917, evidently seeking a place for a nest. Since her prey is Lepidopterous larvae, we cannot accuse her of having come to the bank for prey.

Sphex (*Ammophila*) *procera* Klug. [S. A. Rohwer]. On August 16 this large wasp was seen burying a large caterpillar of the *Noctuidae* [S. B. Fracker]. Since she left her young "on the door step" of the bank, she should be regarded as an inhabitant or a pioneer; but since I took possession of both, she was thus reduced to a visitor.

Odynerus (*Stenancistrocerus*) *unifasciatus* Say. [S. A. Rohwer]. This Eumenid was seen moistening a spot on the bank with water and biting out and carrying away the mud, June 28, 1920.

Polistes variatus was foraging on the rose bush in front of the bank on May 28, 1920. There was hardly any connection or rather only a far fetched one, in the relations to the inhabitants of the bank, in that the *P. variatus* would probably carry off caterpillars which, in the natural course of events would have become food for the inhabitants.

Hoplisus (*Pseudoplisus*) *phaleratus* Say. [S. A. Rohwer]. This species, seen entering a crevice on July 21, 1920, was distinctly new to the bank.

Trypoxylon nigrellum Roh. [S. A. Rohwer]. One was seen foraging for spiders in the old bee tunnels of the clay bank on September 6, 1917.

Miscophus americanus [S. A. Rohwer]. Two females taken from the bank on August 31, 1918, were probably seeking a nesting site.

Vespa germanica Fabricius. In August, 1920, one worker of this hornet visited the bank at short intervals for three whole days, and as described elsewhere, carried off each time a specimen of the Chalcid parasite, *Monodontomerus.*

Pseudagenia architecta Say. The first and only specimen of this wasp was observed on July 7, 1917, to enter many old burrows of the mining-bees. Its behavior was very much like that of its cousin, *P. mellipes* when hunting; hence we suppose that it was foraging. This wasp makes tiny twin cells of mud that are somewhat barrel-shaped.

Megachile generosa Cress. [S. A. Rohwer]. This bee always returned and rested on the bank after I missed capturing her on June 3, 1922, which indicates that her interests were probably other than being merely a visitor.

Halictus pectinatus Rob. [S. A. Rohwer]. A male bee of this species was found dead on the bank, September 6, 1917.

Photopsis sp. One individual was making itself at home on the bank. This wasp is supposed to be parasitic; it had evidently found a host among the population.

Camponotus herculeanus L. subsp. *pennsylvanicus* De G. var. *ferrugineus* Fab. [W. M. Wheeler]. These ants, many of them workers and some with large heads, were going about the bank, often entering burrows. They first appeared in 1921.

Beetles.

Corymbites inflatus Say. [E. A. Schwarz]. This click-beetle was at rest at the foot of the bank on July 16. This beetle, or others of its kind, arriving there would probably have no effect upon the inter-relations of life except as they might fall prey to some of the spiders or vertebrates.

Photinus pyralis Linn. [E. A. Schwarz]. Many of these "lightning-bugs" spent their days near the clay bank about the first of August. Since they are nocturnal insects and are in a sleepy condition during the day, they should have been easy prey to alert prospectors. No actual observations were made, however, on the effect of their presence upon the others.

Hypera (*Phytonomus*) *punctata* Fabr. [E. A. Schwarz]. Two specimens were taken at two distinct places on the clay bank on July 30, 1917. There may have been more, but their coloration is such as to make them almost indistinguishable from their surroundings. They evidently fell prey to the ant-lion and other carnivorous creatures.

Rhadopterus picipes Oliv. [E. A. Schwarz]. One specimen of this beetle was taken July 30 from the jaws of an ant-lion.

Coleopterous larvae. Some which could not be identified were often taken from the ant-lion pits. These had evidently fallen from the vegetation above, and were a considerable factor in maintaining so large a number of thriving ant-lions.

Epicauta marginata Fab. [E. A. Schwarz]. About August 20, several of these blister-beetles were found dead on the bank. On September 4 and 6 there were again large lots of these beetles, all dead. I cannot explain the phenomenon, unless it be that some creature had captured them and then spat them out, dead, because of their bad taste.

Hyperodes humilis Gyll. [E. A. Schwarz]. One specimen of this beetle was taken from the jaws of an ant-lion larva on August 14, 1917.

Opatrinus notus Say. [E. A. Schwarz]. A dead beetle taken from a spider's web.

Harpalus dichrous Dejean. [E. A. Schwarz]. One dead beetle found on top of the bank, September 4, 1917.

Anisotarsus sp. [E. A. Schwarz]. One individual of this species visited the bank on September 6, 1917.

Sphenophorus parvulus. Gyll. [E. A. Schwarz]. This snout-beetle was rescued alive from an ant-lion pit, where the enemy was actively endeavoring to make a meal of him on September 7, 1917.

Arhopalus fulminans Fab. [E. A. Schwarz]. Several of these were found on the bank on May 28, 1917.

Languria mozardi Lat. [E. A. Schwarz]. Three specimens found on the bank on May 28, 1918.

Staphylinus cinnamopterus Grav. [E. A. Schwarz]. Of this rove-beetle, the only visitor was found on July 31, 1918.

Tanymecus confertus Gyll. [E. A. Schwarz]. This snout-beetle visited the clay bank on May 20, 1920.

Orthoptera.

Orocharis saltator Uhl. [A. N. Caudell]. Six of these were on a small plant growing at the base of the bank on July 30. They probably contributed to the food supply of certain predacious inhabitants.

Gryllus pennsylvanicus Burm. [A. N. Caudell]. A small cricket was seen struggling in the jaws of an ant-lion, into whose pit it had fallen on August 14, 1917, and on August 30, one of this species spent a chilly night in one of the bee burrows, and was the first to poke its friendly head out into the light of day next morning.

Ischnoptera pennsylvanica De Geer. An egg-case of this roach was found in one of the old bee tunnels. Just what would have been the chances of survival of the young if they had hatched, we can only surmise. An adult was also found hiding in a crevice on September 6.

Locust nymph. This visitor was found as prey of the stick-bug, *Emesa brevipennis.*

Nemobius carolinus Scud. [A. N. Caudell]. One dead individual on the bank, September 7, 1917.

Melanoplus femur-rubrum. One resting here September 7, 1917.

Tettigidea lateralis var. *polymorpha* Burm. [A. N. Caudell]. On October 3, 1917, several locusts of this species were on the clay bank, probably attracted to the spot for shelter from the cold. One was in the web of *Steatida borealis* Htz., where a battle occurred between the plucky little spider and the big locust.

Hapithus agitator Uhler. [A. N. Caudell]. A male visitor of this species fell prey to a spider, *Phidippus tripunctatus* [J. H. Emerton] on September 6, 1919.

Hemiptera.

Pselliopus cinctus Fab. [H. E. Gibson]. This bug was found in a spider's web on September 12.

Anasa tristis De Geer. While this bug was seldom seen at the bank during the summer, on October 3, a dozen adults were found quietly at rest among the rubbish. Each year they appeared there late in the autumn. These bugs hibernate as adults, and had come to the bank seeking crevices in which to spend the winter. They probably appeared upon the scene too late to influence the lives of others. On one occasion (May 20) a young spider, *Phidippus* sp. [J. H. Emerton], was seen feeding on one of these bugs.

Reduvius personatus L. [A. T. McAtee]. This protectively colored bug, concealed in a crevice was sucking the life-blood from a pioneer inhabitant, *Ancistrocerus fulvipes,* on June 28, 1920, and earlier in these pages I state that this bug was preyed upon by the spider, *Ariadna bicolor.*

Arachnida.

Phidippus clarus Keyserling. [C. L. Shoemaker]. One specimen was found on the bank on July 16, 1917. It was probably in quest of food. This is one of the "wandering" spiders, and its wanderings into the unit were evidently not without purpose.

Phidippus sp. [J. H. Emerton]. A female actually made a permanent home in one of the burrows, where her face could often be seen peering from the doorway, and occasionally she would catch and devour a Chalcid.

Phidippus tripunctatus [J. H. Emerton]. One young one feeding upon a visiting male cricket *Hopithus agitator* Uhler. [A. N. Caudell], on September 6, 1919.

Prosthesima sp. [J. H. Emerton]. A female was walking on the bank, June 28, 1920.

Thanatus lycosoides Emerton. [C. L. Shoemaker]. One specimen found at the base of the bank on September 23, 1917.

Habrocestum pulex Htz. [J. H. Emerton]. One specimen on the bank September 23, 1917, feeding upon an ant, *Crematogaster lineolata.*

Lycosa scutulata Htz. On July 30, 1917, at twilight, a male of this spider was quietly resting at the base of the bank. The Lycosidae are popularly known as wolf spiders; they are vagabond, hunting spiders, spinning no snare but chasing their prey upon the ground. This sly watcher undoubtedly had business to transact at the clay bank.

Lycosa sp. During the first part of August, several were seen repeatedly at the same place. It seemed that twilight brought out these night prowlers.

Xysticus ferox Htz. [C. L. Shoemaker]. One specimen at the clay bank at dusk, July 30. This is one of the crab spiders, and like the others, probably came in quest of food.

Spider. A small unidentified specimen taken from the jaws of the ant-lion on September 3, 1917.

Pardosa sp. [J. H. Emerton]. This was another of the wandering hunters which came to the bank October 3, when food elsewhere became scarce, and one specimen was walking about on the bank one sunshiny morning of February 26, 1921.

Drassus sp. [J. H. Emerton]. One at bank October 3, 1917.

Gonyleptes sp. Several of these daddy-long-legs were on the bank, and about a dozen had congregated on a small plant on July 30, 1917. Warburton* says the members of this group are "without doubt essentially carnivorous." Hence the presence of these was probably of serious significance, especially to the smaller species of residents.

Ixodes sp. This tick was abundant each year at the end of July and in the early part of August among the old lumber on top of the bank.

Myriapoda.

On several occasions during 1917 and 1918, dead specimens of Myriapods were found on the bank. Since none

*Cambridge Nat. History 4:44, 1909.

were found alive and often the dead ones were partly disintegrated, and since these species are known to limit their habitation to rotten woods, I could think of no explanation for their presence here in such condition except the far-fetched theory that they had been brought here by other animals, possibly lizards, and abandoned or spit up. Among those thus found were *Euryeurus erythopygus* Brandt. [R. V. Chamberlain], *Cleidogona caesioannulata* Wood. [R. V. Chamberlain], and *Julius* sp. [R. V. Chamberlain].

Résumé of Visitors.

The following table recounts species found among the visitors to the clay-bank community:

Snake,	
Lizards,	
Toads,	
Phoebe bird,	
Red bird,	
Ground mole,	
Man,	
Lepidoptera,	*Pyralis cuprealis.*
Caterpillars,	*Pyralididae* and *Noctuidae.*
Lepidoptera,	*Pseudaglossa lubricalus.*
Catocala moth,	*Catocala innubens.*
Moth,	*Herculia olinalis.*
Wasp,	*Pompiloides sp.*
Spider wasp,	*Arachnophoctonus ferrugineus.*
Wasp,	*Pompiloides americanus.*
Wasp,	*Tachytes peptictus.*
Wasp,	*Silaon sp.*

Wasp,	*Sphex nigricans.*
Wasp,	*Sphex procera.*
Wasp,	*Odynerus unifasciatus.*
Paper wasp,	*Polistes variatus.*
Wasp,	*Hoplisus phaleratus.*
Wasp,	*Trypoxylon nigrellum.*
Wasp,	*Miscophus americanus.*
Hornet,	*Vespa germanica.*
Pompilid wasp,	*Pseudagenia architecta.*
Leaf-cutter bee,	*Megachile generosa.*
Bee,	*Halictus pectinatus.*
Parasitic bee,	*Photopsis sp.*
Ant,	*Camponotus herculeanus.*
Beetle,	*Corymbites inflatus.*
Lightning beetle,	*Photinus pyralis.*
Beetle,	*Hypera punctata.*
Beetle,	*Rhabdopterus picipes.*
Beetle larva,	Unidentified.
Blister beetle,	*Epicauta marginata.*
Beetle,	*Hyperodes humilis.*
Beetle,	*Opatrinus notus.*
Beetle,	*Harpalus dichrous.*
Beetle,	*Anisotarsus sp.*
Beetle,	*Sphenophorus parvulus.*
Long-horned beetle,	*Arhopalus fulminans.*
Beetle,	*Languria mozardi.*
Rove beetle,	*Staphylinus cinnamopterus.*
Snout beetle,	*Tanymecus confertus.*
Orthopteron,	*Orocharis saltator.*
Cricket,	*Gryllus pennsylvanicus.*
Wild roach,	*Ischnoptera pennsylvanica.*
Cricket,	*Nemobius carolinus.*
Locust,	*Melanoplus femur-rubrum.*

Orthopteron,	*Tettigidea lateralis* var. *polymorpha.*
Orthopteron,	*Hapithus agitator.*
Bug,	*Pselliopus cinctus.*
Squash bug,	*Anasa tristis.*
Bug,	*Reduvius personatus.*
Spider,	*Phidippus clarus.*
Spider,	*Phidippus tripunctatus.*
Spider,	*Phidippus sp.*
Spider,	*Prosthesima sp.*
Spider,	*Thanatus lycosoides.*
Spider,	*Habrocestum pulex.*
Spider,	*Lycosa scutulata.*
Spider,	*Lycosa sp.*
Spider,	*Xysticus ferox.*
Spider,	*Pardosa sp.*
Spider,	*Drassus sp.*
Daddy-long-legs,	*Gonyleptes sp.*
Tick,	*Ixodes sp.*
Myriapod,	*Euryeurus erythopygus.*
Myriapod,	*Cleidogona caesioannulata.*
Myriapod,	*Julus sp.*

The list totals 71 species, and covers a number of forms, from man down to Myriapoda. No attempt was made to list the microscopic organisms, although with proper equipment an interesting list of such specimens could doubtless have been found.

It is interesting to note that of these 71 species which were found visiting the clay bank coincident with my intermittent visits 7 were vetebrates, 5 were species of Lepidoptera, 18 Hymenoptera, almost all of which were wasps, 15 were beetles, 7 Orthoptera, 3 species of bugs, 10 Arachnida and 3 Myriapoda.

It will be seen that some of the creatures were of little or no importance in the balance of life on the clay bank; for instance the squash-bug, *Anasa tristis,* which is a vegetable feeder and which few creatures would eat, would have little influence on the life of the social group. On the other hand, some of the visitors wielded a significant influence, as in the case of *Vespa germanica* which carried off the Chalcid parasites which preyed upon the bees. Many of the visitors might be placed alternatively in still another group, those which might properly be considered as either renters or pioneers, as for instance, the spider-hunter, *Pseudagenia architecta,* which might be said to carry on its daily business at the bank, although it maintained its home elsewhere. Of course the sharp line of demarcation between the groups is difficult to define while the possibility is always open for the visitors to become residents there and participate in all the joys and sorrows incidental to influencing the balance of nature already present, by preying, by being preyed upon or by parasitizing other creatures or by becoming hosts for other parasites.

(e) Parasites.

The following account presents the details of the activities of the last group of the inhabitants of the bank, the parasites, which affected the pioneers and the renters. These exerted their influence upon the balance of population in a variety of ways, and in turn were influenced in interesting ways by some creatures from all three groups.

Parasitic Hymenoptera.

Chalcid parasites, *Monodontomerus sp.* [J. C. Crawford].

When the observations began on June 25, 1917, and the *Anthophora* bees, etc., first appeared that spring, hundreds of these parasites were at once on hand. Their emergence was almost simultaneous. The number on this first day of my visit was so great as to make me fear the appalling mortality that must be in store for their hosts, the bees, even if only a small portion of them were to be permitted to beget offspring. They were actively searching over the bank, entering burrows and dancing before the bank in the bright sunshine. I could then get direct evidence only that they had come from the cocoons of *Anthophora abrupta,* but they were undoubtedly parasitic upon other species as well, since they were found at the bank also in the fall, and the bees, *A. abrupta,* ended their life cycle in July. One burrow of the mining-bee, when opened, exposed to view fifty *Monodontomerus* adults; I could not be absolutely sure, however, that all of these were young parasites just emerging from this cell; it is possible that some of the sun-dancers had left their companions and crowded into this cell of mixed sexes. In 1920, on July 24, 13 cells of this *Anthophora* bee were taken into the laboratory, only four of which proved to be infected by this parasite. These four cells gave forth 139 adult parasites, 109 of which were females and 30 males, or an average of about 35 for each bee cell. At such an alarming rate of increase, it is surprising that any bees at all should have escaped them.

These parasites throve and appeared in large numbers in each of the seasons of observation. There is more than one generation each year. This made a particularly difficult situation for the species of hosts which produced but one generation each year. The first adults that emerged in the spring, lived and disappeared simultaneously with the *Anthophora* that closed their life cycle about the middle of July. The eggs deposited by the first lot of adult parasites produced adults later in the summer. A careful and frequent examination showed that the Chalcids were not in evidence from the time of their waning and first disappearance, July 16, up until September 3, when they re-appeared after an interval of forty-eight days. This second generation also comprised an enormous population. Many of these were seen also to enter the bee burrows, and some of the bee cells dug up later also contained these Chalcids in the pupal stage.

Not all of them succeeded in their parasitic plan of existence; some fell prey to other inhabitants early in life. On the first day of the appearance of the second brood, seven were taken dead from the spiders' webs nearby, and elsewhere in these pages is recorded the fact that *Vespa germanica* was making regular trips, carrying them off day after day to her nest.

On September 6, while the numbers flying about seemed just as great, still many were found dead about the bank; I cannot account for this, since this early date seems hardly time for a natural death. These may have been the dead of the previous generation, or those of the present generation that had perished before emergence, which some industrious *Trypoxylon* wasps had swept out of the old burrows that they were renovating for their own use. Mortality was really upon them, however, because by September 12 a marked reduction in their numbers was easily noticeable. On October 3, none at all were abroad, but of course at this date practically all of the life on the bank was still.

In 1918, when the carpenter-bees, the *Anthophora* mining-bees, and the caterpillar wasps all appeared a month earlier, about May 25 (because of temperature conditions), these Chalcid parasites too appeared a month earlier. All of the life in the bank responded to the same laws. In 1918 these parasites were just as numerous but I was surprised to note no increase over the previous year. It would have seemed reasonable to expect that the myriads of the last year would have multiplied as greatly, at the expense of everything else, that this year there would be little or nothing but Chalcids. But to our surprise the *A. abrupta* bees, even under such persecution, were more abundant the second year than the first. This is a good example of the delicate balance in nature's game of cat and mouse.

By June 28, 1918, as many chalcids were dead and strewn about the bank, in burrows and in crevices, as were alive and on the wing; thus that date marked the decline of the first generation, which in the preceding year occurred on July 15. Some*Anthophora* cells taken a little latter contained live pupae. So, comparing the dates of this species for 1917 and 1918, we see that when the first generation got a thirty days' earlier start, so likewise did the second generation.

In 1920 this species appeared in about the same numbers, and the interval dividing the two generations again came in July. To be exact, on my visit on July 21, not one Chalcid was to be seen. But on the next inspection, September 2, they were out again in great numbers. These of the second generation were, in turn, all gone the first of October. The dates of these two generations were practically the same as in the first year; the first generation ran from late June to mid-July, and the second appeared about the first of September but disappeared before the end of the month.

The animal most abundant in an ecological unit should be regarded as the dominant one. If this rule includes parasites, then we must admit that this Chalcid is the most abundant and dominant insect in the unit. They were already plentiful at the time of my first observation; their hosts were well established and numerous, and since each host is capable of bringing to maturity, on an average, thirty or so parasites, we see how favorable were all their prospects. And yet we come face to face with the fact that other parasites, Diptera, etc., even though they appear in far smaller numbers, did fully as much destruction to the permanent residents of the bank as did these many little Chalcids. What does it matter to an *Anthophora* larva, whether it yields its life to produce thirty-nine chalcids or one cuckoo-bee?

Thus, we see that the most important aspect of the life of the Chalcids is to keep the bees from overrunning everything by their enormous increase in population, which would doubtless take place without this deterring influence. As a secondary function they serve as food for some species that in no other wise influence the life of the bank, such as non-resident *Vespa germanica,* and also to feed spiders which, by being thus encouraged to come to or stay on the bank, might also prey upon the other residents.

Cuckoo-bees and parasitic wasps.

These beautiful green bees, parasitic upon many forms of Hymenoptera, appeared about the bank during every season of the term of observation. They were directly parasitic upon many of the inhabitants, and were frequently observed following a returning mother to her nest, and were often seen prowling about and entering the nests of others.

Only one species was found, *Chrysis* (*Tetrachrysis*) *coeruleus* Fab. [S. A. Rohwer]. These cuckoo-bees appeared with the first life on June 25, 1917, and were in almost constant attendance at the bank in summer from that date until near the middle of October. They appeared in great abundance in early summer, flying before the bank in the sunshine, searching over the surface and entering numerous crevices and bees' tunnels, evidently taxing the legitimate life in the bank as much as did the Chalcids. Their numbers seemed to increase as summer advanced; but numerical estimates of this population are difficult to make at the early season. One may count the turrets of the bees, the pits of the ant-lions, or the webs of the spiders, but these transients sneaking about the dwellings of others, could not be definitely enumerated.

The next year by August 10 their number seemed much reduced; on August 14 only one specimen was seen, and none thereafter, excepting dead ones at the foot of the bank. One carcass of this bee was removed from the web of a spider. This was probably the natural time for the death of these bees, and we thought that a new generation would appear soon after. It was interesting to discover that with the disappearance of the cuckoo-bees, the silver-winged parasitic Dipteron made its appearance.

On August 30, only one cuckoo-bee was present; this seemed a forerunner of the second generation, rather than a straggler from the first, for the next day three were out, and thereafter they increased briskly until a thriving second generation was out and in action. From September 4 to 6 this population was at its height; by September 12 they, along with the other species then about the bank, began to disappear as the chill nights came on, but whether they perished with the cold, or made their natural demise, or merely were in hiding, I cannot say with certainty. However, on one late September day, when the bank became warm in the sunshine, two appeared; one was especially active in annoying a turret-bee. No doubt many of these parasitic bees died in their burrows. Their latest date recorded was October 13.

Few of these superchitinous insects fall prey to the hungry neighbors. The rule "to eat and be eaten" does not apply to the cuckoo-bee, which appears to be the armadillo of the insect world.

Pseudomelecta interrupta Cress. [S. A. Rohwer]. This bee was seen only once at the clay bank, on July 21, 1920. It entered one of the nests of *Anthophora*, and was taken for identification as it emerged several minutes later.

The species must have a highly interesting life history, for Wheeler (Proc. Am. Phil. Soc. 58:14. 1919) classifies it as one of the parasitic bees, derived from the ancestral genus *Anthophora* and probably parasitic on *Anthophora*. He questions this later statement, but since it entered the burrow of *Anthophora* after the manner of a parasite, I think much doubt as to its habits is removed. This of course would mean that *P. interrupta,* having at some time been derived from the genus *Anthophora* has found a way to escape the *Anthophora* responsibilities of mining and food gathering by turning parasitic on its own kin, just as seems to be the case with *Psithyrus* in the nest of *Bombus.*

Mutillids. The cow-killers or velvet ants, with wingless females and winged males, are well known to be parasitic, and their way of prowling about the clay bank indicates that, like many of our own species, seeking hosts is the sole ambition of their lives. They undoubtedly found hosts in the clay bank.

Dasymutilla ferrugata Fab. [S. A. Rohwer]. On June 28, 1917, one female was seen to enter a dozen burrows of the *Anthophora* bee, and in some it remained a sufficiently long time to have done mischief. Other mutillid parasites, which remained unidentified, were seen doing precisely the same on July 31, and August 10.

Sphaerophthalma scaeva. Two females of this parasite were darting about as if on mischief bent, on August 30, and on the next day a half-dozen or more were seen. We have previously reared these parasites from the old nests of the mud-dauber, *Sceliphron caementarium.*

On the clay bank, besides *D. ferrugata* and *S. scaeva,* one would occasionally pick up an unknown specimen of the Mutillids; I suspect that they were seeking hosts, but their numbers were so insignificant in comparison to the other parasites that I do not think they were to be regarded as a "real force in the community."

Sphaerophthalma pennsylvanica Lep. [S. A. Rohwer]. A small elm shrub, between the clay bank and the rose bushes, seemed especially attractive to a large variety of insects. Flies and parasitic Hymenoptera were particularly abundant in variety, but for large numbers of a single species only two were notable; they were *Chalybion caeruleum* males, discussed elsewhere in these pages, and males of this species. There was another similar shrub near by, but no such insect population was apparent upon it, so I concluded that it was the aphids present here which had attracted them to this one, although I could see no actual relationship expressed in their activities. Perhaps in both species, the males were merely marking time until the appearance of the females. It is interesting to note, however, that while the males were so near to the clay bank on this occasion, they probably flew here from elsewhere, for the females of this parasite have never been seen at the bank.

Sapyga sp. [S. A. Rohwer]. One was walking about on the bank on June 29, 1917. Members of this family are, according to Rohwer (Conn. Nat. Hist. Survey 22:620. 1916), parasitic on bees and wasps, while Packard (Guide to Study of Insects, p. 134. 1876) says that in Southern Europe *Sapyga repanda* is parasitic in the nests of *Xylocopa violacea;* Sharp, however, (Insects, Pt. 2, p. 100) says that *Sapyga* 5— *punctata* was seen carrying caterpillars.

Sphecodes sp. Two specimens of this red-bellied parasitic bee were seen going in and out of the burrows of the resident bees on June 28, 1920.

Diptera.

Of all the Diptera taken at the bank, not one specimen was other than parasitic; the group as a whole may be justly regarded as doing as much damage to the lawful inhabitants as either the *Chrysis* or the *Chalcids.* The Diptera, however, came later in the season, and possibly sought different victims. Dipterous parasites were first seen on July 30, 1917—a half-dozen representing two or three species. As days went by, they became more numerous in species and numbers. The details below relate their activities.

Copecrypta ruficauda Coq. [C. H. T. Townsend]. This fly was seen to rest for several minutes on the clay bank on August 10. While I was wondering how I could capture it, it flew to my wrist and became so intent on drinking the perspiration that I picked it up easily in my hand. It was the only specimen seen there.

Archytas aterrima R. D. [C. H. T. Townsend]. This fly belonging to the family *Tachinidae,* and commonly called the tachina fly, is parasitic on other insects. One specimen was taken at the bank on July 31. Like *Copecrypta ruficauda,* this fly was taken when it flew to my hand to drink the perspiration.

Sarcomacronychia trivittata T. [C. H. T. Townsend]. The first time this fly was seen at the bank was September 6, when two specimens were taken. They spent their time flying about the bank, often resting upon it and seldom going far away from it; this conduct indicated that there must be some attraction there. A third individual was observed on October 3, 1917.

Parametopia sp. [C. H. T. Townsend]. One such pest was seen to follow the wasp, *Ancistrocerus fulvipes,* as she entered her nest laden with a caterpillar on September 12. A second individual was seen to follow the same species of wasp on October 3, 1917, as she was going to the nest. This does not mean that this fly has become so specialized as to require a specific host, for we have often seen it behave so with other wasps elsewhere.

Argyromoeba anale Say. One specimen of this parasitic fly was on the bank September 7, 1917.

Argyromoeba oedipus Fab. [F. Knab]. Six specimens of this parasite were seen about the clay bank on July 31, one of which actually entered a burrow of the white-banded bee, *Entechnia taurea.*

Argyromoeba fur O. S. [F. Knab]. One was at rest on the clay bank on September 3, 1917. In 1918, this species, along with all the other life in the unit, appeared about a month earlier, or on May 28. (The 1918 material was identified by C. T. Greene.)

Argyromoeba tigrina De G. [F. Knab]. This parasitic fly (Fig. 18) first appeared on August 8, 1917. At first there were only three individuals; two days later they were present in very great numbers. They frisked and flitted about in the sunlight, stopping to rest for long periods on the wooden part of the porch and in the direct sunlight. When at rest thus they could easily be picked up with the fingers. The peculiar life history of this fly enables us to know absolutely that they had not flown to the bank from afar, but had actually emerged on the scene. The tell-tale evidence is this: in transforming to adulthood, this species leaves the home of its host while it is still in the pupal stage and, upon gaining its freedom transforms into the adult and leaves the old shedding-skin (Fig. 19) on the surface near the point where it emerged. In many places on the face of the clay bank, and at its base, up among the wooden partitions very near to the tunnels of the carpenter-bees, *Monobia* wasps or grass-carrier wasps, and even protruding from the bee burrows, were these shedding skins adhering conspicuously. This indicated just which species were probably their hosts. That they were quite numerous I was also certain, since I picked up more than sixty of these shedding-skins, and of course these were not all.

While there is sufficient evidence that these parasites prey upon the inhabitants, and while they spend most of the sunshiny hours each day in flying to and fro before the openings of the burrows or resting near by, and although I have watched for hours at a time, I have never yet seen one of these creatures attempting to enter a burrow. I especially watched for this, since the great Fabre has discovered for another species of this genus some complicated aspects of life history. True I have often seen the females hovering over a burrow, poising on the wing above the aperture and dipping down again and again, much in the manner of a dragonfly depositing her eggs under the water, and I suspected that with each dip she deposited an egg but, like Fabre, I have never discovered the egg. Fabre seems to think, for his species, that the parent fly oviposits by merely dropping a minute egg while flying over the surface of the mud walls which contain the grubs of the host, and that the larvae hatching from the eggs are wonderfully adapted for breaking into the masonry to reach the host by being provided with a very horny, deflexed head, armed in front with stiff bristles and under the body with several pairs of elongate setae serving as organs of locomotion. In the species under present consideration, the eggs are probably deposited in this manner, although some other species of this genus, as *A. oedipus*, are known to enter the bee burrows. Several females of *A.*

tigrina were seen repeatedly to fly violently against the wood beside the *Xylocopa* or other burrows; then often I could see the tip of the abdomen enlarge, as it was bent downward and tightly pressed against the rough surface, and moved in a circular motion as it rubbed against the wood. In only one instance did I actually see something fall, but I was not near enough to see whether it was an egg or excrement. So the problem of the life history of this parasite remains unsolved.

It would at first appear that *A. tigrina* came too late in the season to affect the bees, *Anthophora abrupta,* since their lives had terminated before the advent of the parasites. This might be true, and *A. tigrina* might not affect this species but might be a direct cause of the gradual lessening of the numbers of the white-banded bees, *Entechnia taurea,* which were contemporaneous. However, if Fabre's theory holds true for this species and these parasitic young possess those wonderful adaptations for reaching their host even through prison walls, then the parasites would affect the dormant generation of *Anthophora,* and other species as well. There is additional evidence, however, in the fact that I found the shedding-skins on the face of the bank, but not on the top, and *A. abrupta* builds only in the face of the bank. This would lead us to think that *A. abrupta* is a host despite the fact that the adults are not contemporaneous.

I want to repeat that in constant watching during these dipping maneuvers, I failed to see an egg drop, but from the insect's behavior I felt sure that something was happening. It is reasonable to believe that the egg is minute, and with the observer four feet away (one cannot successfully come closer) something might happen beyond one's sense of sight.

These adults are flower-loving insects. On August 13, two specimens were seen on flowers in a field some distance away. It may well be that this would account for the reduced numbers during the morning hours, while at noon they were present in full force; perhaps they were out in the blossoms satisfying their morning hunger, or again perhaps they had gone out into the vegetation to spend the night (their sleeping habits have not yet been ascertained) and were slow in returning to the day's activity. With the cold nights of early September they began noticeably to wane, and none were seen alive after September 12.

These flies were seen throughout the season in varying abundance. It seemed at first that with their playing and dancing about the bank they were merely marking time, but, since they continued it all summer, it appears that they are the kind of beings that can seemingly dance and frolic through life and yet make a success of living. Some were seen in copulo on July 26, 1922.

One pair remained in copulo, back to back, for a half-hour, resting on a shady portion of the bank.

In 1918, this fly was no exception in the phenomenon of all life appearing a month earlier. A few individuals were seen out on July 17, 1918, as against August 7, 1917. Until the end of July they were very abundant, and like their ancestors of yesteryear, they kept busy most of the time, doing nothing in particular, unless they oviposited on the sly. The shedding-skins as well as the flies gave evidence of an increase in population. This increase was probably at the expense of the dwellers in the wood-tunnels above, for as I have already shown, these and the white banded bees declined simultaneously with the increase in this parasite.

I do not know what happened to the species in 1919, but in 1920 they appeared in limited numbers, and in 1921, they were again on the increase.

This fly evidently has a sensational criminal life history, which I hope some day will be brought to light.

Ganperdia apivora Aldrich [J. M. Aldrich]. In June, 1920, a dozen or more specimens of this red-eyed diptron were flying about the burrows in the clay bank, in a manner strongly indicating parasitic habits, although I did not at any time actually see them enter the burrows, and the same observation was made on May 27 to May 28, 1921. These bees are undoubtedly parasitic on the mining bees in the clay bank, since I actually observed them hatching in the laboratory from cells of *Anthophora abrupta* on May 20 to 22, 1921, from material taken about nine miles north of the clay bank.

This species is described by J. M. Aldrich* from specimens taken near St. Louis in 1877. It is very interesting, too, that forty-five years ago this fly was found in a clay bank about the nests of the mining bee, *Anthophora abrupta.* That it is parasitic upon these bees is evident from the statement in the paper cited, that one of the bee cells contained cocoons which gave forth adult flies of this species in the following Spring.

In the first week of June, 1922, hundreds of these red-eyed flies were out at the bank and were then being freely preyed upon and devoured by the lizard (*Cnemidophorus sexlineatus*) which made itself at home about the place.

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*Proc. Ent. Soc. Wash. 21:106. 1919.

Lepidophora lepidocera Weid. [C. T. Greene].

This parasite was present at the clay bank on July 1, 1922. It was often seen bobbing up and down on the wing before the burrows, but if eggs were dropped in the process, none were ever discovered.

Parasitic Beetles.

Hornia minutipennis Riley [E. A. Schwarz]. This beetle, which is parasitic upon the mining bees, was found only twice at the clay bank. One was taken at the base of the bank on May 27, 1920; it deposited many eggs in captivity the next day, and died soon after. Another was taken from the cell of *A. abrupta* on October 2, 1920; it emerged in the warm laboratory on March 19, 1921, promptly ate of a piece of apple and consumed part of an *Anthophora* larva which was given it; the remainder of the larva it allowed to dry up. It lived five weeks.

C. V. Riley* describes this species from specimens reared from the cells of *Anthophora sponsa* taken from clay banks near St. Louis. Pierce† tells us that the genus *Hornia* is known to be parasitic on Hymenoptera; the larvae are conveyed to the host by some other insect —that is, they are passively conveyed. Their feet are specialized for clinging, not digging. Their food is generally honey; hence the mouth parts are reduced. *Hornia* shows degeneracy in the adult stage with complete loss of the wings, and almost entire reduction of the elytra.

Fabre‡ has found a parasitic beetle, *Sitaris humeralis*

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*Trans. Ent. Soc. St. Louis, 3:563-565. 1877.
†Univ. Nebraska Studies, 4:153. 1904.
‡Sharp, Insects. Pt. II, p. 272.

by name, living at the expense of bees of the genus *Anthophora.* "The eggs of *Sitaris* are deposited in the earth in close proximity to the entrances of the bees' nests, ... a single female producing upwards of two thousand eggs. . . . . . They hatch in about a month, producing a tiny triungulin of black color; the larvae, however, do not move away, but, without taking any food, hibernate in a heap until spring, when they become active. Although they are close to the abodes of the bees, they do not enter them, but attach themselves to any hairy object that may come near them, and thus get onto the bodies of *Anthophora* and are carried to the nest." At first it seemed strange that at the clay bank at Wickes they were present only in such small numbers, but this is explained by the statement from the same work that the triungulins distribute themselves on all sorts of unsuitable insects, so that it is possible that not more than one in a thousand succeeds in gaining access to the Anthophora nests.

Résumé of Parasites.

To summarize this group, I have found in the clay bank parasites to the number of 19 species. This is highly interesting in the light of the relation of this number to the number of pioneers and renters. Of the first there were 18 species, many of which could not possibly be host of these parasites; of the latter there were 11 species, including spiders and others which likewise could not serve as host. Leaving out of consideration all the non-host species of both the pioneers and the renters, we find the parasites greatly outnumbering legitimate residents of either class.

The following table recounts the parasites that visited the bank.

Parasites.

Chalcid parasite,	*Monodontomerus* sp.
Cuckoo-bee,	*Chrysis* (*Tetrachrysis*) *coeruleus.*
Parasitic bee,	*Pseudomelecta interrupta.*
Cow-killer or velvet ant,	*Dasymutilla ferrugata.*
Cow-killer or velvet ant,	*Sphaerophthalma scaeva.*
Cow-killer or velvet ant,	*Sphaerophthalma pennsylvanica.*
Parasitic Wasp,	*Sapyga* sp.
Parasitic Bee,	*Sphecodes* sp.
Parasitic Fly,	*Copecrypta ruficauda.*
Parasitic Fly,	*Archytas aterrima.*
Parasitic Fly,	*Sarcomacronychia trivittata.*
Parasitic Fly,	*Parametopia* sp.
Parasitic Fly,	*Argyromoeba anale.*
Parasitic Fly,	*Argyromoeba oedipus.*
Parasitic Fly,	*Argyromoeba fur.*
Parasitic Fly.	*Argyromoeba tigrina.*
Parasitic Fly.	*Ganperdia apivora.*
Parasitic Fly.	*Lepidophora lepidocera.*
Parasitic beetle.	*Hornia minutipennis.*

It will be seen from the table that, with the exception of one beetle, all of the parasites belonged to the orders Diptera and Hymenoptera. Of the former there were 10; of the latter, there were 8, comprising one chalcid, three species of cow-killers or velvet ants, one wasp and two species of bee which only recently phylogenetically speaking, have acquired parasitic habits, and one species of cuckoo-bee. With this appalling array it is a wonder that any host can continue to exist; there is no telling how many species have already become extinct through this agency during the existence of the clay bank.

(C) RELATION OF POPULATION TO ENVIRONMENT.

(a) Relation to Temperature.

Insects know not dates; May or December, June or January mean nothing to them other than heat or cold. The insects' calendar is the thermometer. Instead of saying that all the spring Hymenoptera, regardless of species, emerged during the latter part of June, I should say that they emerged when the average mean temperature for fifteen days reached 73°. Let us not forget that June has nothing in its makeup to mean anything to the Hymenoptera, but 73° for fifteen days at the springtime of the year means to them life, sunshine and food.

My attention was first attracted to this phenomenon in noting that in 1918 the life appeared from the clay bank about a month earlier than in 1917, and in 1920 they appeared at almost the same time as in 1918. In other words, the hymenopterous life about the place was in its spring fullness on June 25, 1917, May 28, 1918, and May 30, 1920. The average mean temperature for the fifteen days preceding and including June 25, 1917, was 73 1/25°; the average mean temperature for fifteen days preceding and including May 28, 1918, was 73 4/25°; and for the same period preceding May 30, 1920, was 73 1/2°. These temperature figures of course are only relative; the clay bank was facing the eastern sun, whereas, the temperature records were made in the shade; let us remember, too, that the life potential buried in the clay bank was likewise in the shade.* This corre-

*The temperature records are from the U. S. Meteorological Reports taken at St. Louis, twenty miles north of this site.

lation works out so beautifully that I shall want to place this material experimentally at a temperature of 73° in November or February, to see if then the development and maturity occurs likewise. Had the 1917 population (which emerged in abundance about June 25th) emerged on May 28, as did the 1918 lot, it would have spent the 15 days before its emergence at a temperature of 66 2/15°.

This temperature phenomenon seemed to hold in general for most of the spring Hymenoptera, and I found them all appearing at one time, after the manner of *Anthophora abrupta* for example. The bank yielded its contents of this species all at one time each year, within a space of two or at most three days. Simultaneously appeared also their Chalcid parasites, *Monodontomerus.* The green cuckoo-bees burst forth at their appointed time, and so too the caterpillar wasp, *Ancistrocerus fulvipes;* the *Monobia* mud wasp, the *Trypoxylon,* etc., etc. The only exception was the carpenter-bee, *Xylocopa virginica* which appeared some time earlier.*

This species is a wood dweller—not a cave dweller—and would, therefore, be influenced by temperature somewhat differently from those which live in the compact earth. Not alone in 1917 did I see this simultaneous emergence of the various species and of all individuals of each of these species, but in 1918 and 1920 as well. It was as though some one touched an electric button and that button was labeled 73° F.

The white-banded bees *E. taurea* and the dipterous parasites, demanding a higher temperature and hence

*We do not know how this bee hibernates, but observations given elsewhere indicate a period of hibernation in the adult stage.

emerging later, conformed nicely to the precedent set by the spring Hymenoptera in the year 1918, when the meteorological conditions were very different from 1917. This bee population emerged in 1917 on July 16 and in 1918 with a more favorable temperature 18 days earlier on June 28. In this species I found, in so far as the records were kept, that they responded, by emerging from the pupal condition, to a temperature of 77°. Using the same weather records as a basis, we find that for the fifteen days preceding their emergence on July 16, 1917, we had an average mean temperature of 77 2/15°. In 1918, their appearance was earlier, June 28, and the average mean temperature for the period of fifteen days preceding this was 77 2/3° F.

Thus, we can see in the emergence of this hymenopterous population a very definite response to temperature, and not an emergence correlated with the length of time the organisms had spent in the ground as larvae or pupae. This is quite reasonable, as is already known, the time spent in the various stages is lengthened by cold, and the development is accelerated by warmth. All this seems, in so far as these Hymenoptera are concerned, not to apply merely to a single species, but to indicate a law influencing all life under these conditions.

(b) Relation of population to light and sunshine.

The Hymenoptera are generally regarded as lovers of the light and sunshine, and especially is this true of the flower-frequenting bees and wasps; they are generally to be seen foraging among the blossoms, and then indeed may we call them children of the sun. Here we are interested in the three phases: (a) the relation of the position of the nests to the sunlight, (b) the relation of the sun-loving parasites to the position of the nests of their hosts, and (c) the action of parasite toward host as the nest of the host is in the sunny or the shady portion of the bank.

Position of the clay bank in relation to the sunlight.

We have seen in Fig. 2, how the clay bank was protected above by the porch and faced the eastern sun. Three clumps of rambler rose-bushes stood in front of the bank, one at the north end and two spread over the south half. These were densely covered with flowers and foliage during the summer.* Since two rose-bushes were in the southern half, the portion of the clay bank just behind them was much more shaded than the northern half.

In this brilliantly illuminated area between the bushes the nests of *A. abrupta* abounded; here they left their old burrows, an unmistakable record of the life which had been there. It was in this portion of the bank also that in 1917, the most of the contemporaries of the *Anthophora* congregated to build their nests. It would be better to say that here they emerged, and then remained in almost the precise spot to nidify, but this in turn only means that their ancestors at some time actually chose this spot or congregated here, so the significance is the same. In order to realize the sharp contrast in the nesting activities, between the sunny portion of the bank and the shaded areas, Figs. 3 and 4 may be compared. Fig. 4 shows the northern half (the photograph was taken after a dry year, when few bees made turrets, and these few had fallen or had been

*This picture was taken in October, when most of the foliage had fallen.

harvested for study), or that portion which got the maximum amount of sunlight. This is in striking contrast to Fig. 3, the southern half, which enjoyed only a little filtered sunlight. One can readily see that the degree of illumination made a great difference in choice of site by the *A. abrupta.* The white-banded bees, *Entechnia taurea,* the caterpillar-wasps, *Ancistrocerus fulvipes,* and the *Trypoxylon* wasps did not give evidence of so direct a dependence upon this factor. I have often wondered just what is the correct explanation of this correlation of warmth to longevity. I have discovered in other studies that in organisms that take no food as adults (Saturniid moths) increased warmth tends to accelerate the activity and thus exhaust the vital energy so that the life of the organism is cut to a much shorter duration than it would have been at a lower temperature where activity is retarded. So shall we say that because *A. abrupta* chooses the warmest place in the sun, her activity is intensified and her life soon spent? Or, on the contrary, shall we say that her habit of choosing the sunny situations is a fortunate adaptation in that it enables her to get through with the necessary duties of life in the short period of time allotted to her, and that probably only those individuals which do exercise this choice will be able to finish their life-work and leave progeny? It should be noted that all the other insects mentioned in this study have a much longer time for their duties than *A. abrupta,* since they either lived the entire season, or had more than one generation each season.

In 1917, the white-banded bees greatly outnumbered the *Anthophora.* While a few of the nests of the former were in the face of the bank, and often took a somewhat vertical position (Fig. 20E) most of them were horizontally resting on top of the bank, near the edge (Fig. 21E). All of the nests of this species enjoyed an abundance of the sunlight; those on top of the bank were made very near to the front edge. However, during the years that followed this species decreased in numbers so that by 1920 it was barely holding its own, whereas *A. abrupta* increased amazingly, as described elsewhere. Another interesting factor enters into the story here, however; during the years under observation the white-banded bees gradually extended their nesting area. In 1917 most of them were in among the *Anthophora* nests near the sunlight, either in the face of the bank or near the edge of the top (Figs. 20E and 21E) with merely the beginning of a settlement at the extreme south end and another at the north end. In 1918, they were almost all in these two end groups, and none among the *Anthophora* nests. In 1919 a few were at the south end, but most of them were on the top, farther back than previously, and in 1920 to 1922, all of the burrows found were far back on the bank and entirely out of the direct sunlight. In the meantime *Anthophora abrupta* was increasing in numbers, always building on the sunny face of the bank. Moreover they were gradually spreading over the southern portion of the bank, until by the end of the period the north half of the dark barren portion seen in Fig. 3 was abundantly inhabited; Fig. 22 is the same area as in Fig. 3. Not without cause, however, was this significant change; in the spring of 1918 the tenants of the house had cut the ramblers almost to the ground, so for the seasons immediately succeeding, that portion of the bank was also fully exposed to the sunlight.

The parasites also love the sunlight. This point leads us at once into a maze of interrelations between sunlight, parasites and hosts. The very short life cycle of *Anthophora abrupta* eliminates from consideration practically all of the Dipterous parasites, because by their early emergence they escape the parasites and their succeeding generation is practically provided for before the most of the parasites are born. Hence *Anthophora* has to struggle against only the Chalcids, the cuckoo-bees and possibly one species of Diptera in order to maintain her species. While these three parasites did evidently prey upon this *Anthophora* population to some extent, their success depended to a far greater extent upon the white-banded bees as hosts since the duration of the life of the latter was more than twice that of the *Anthophora* bees, and since the white-banded bees emerging later in the summer were the possible hosts of more than three times as many species of parasites. It is little wonder then, that the species which was being rapidly exterminated left the sunshine and the enemies which swarmed in it, and sought the ill-lighted recesses of the bank. Of course, it is really a problem whether these bees actually left the sunshine and crept away, or whether the parasites had merely exterminated all those which persistently remained in the sunny areas. With nations of bees—as with nations of men—there is not place in the sun for all. The numerous and the mighty occupy the favored places, and any others that wish to live may occupy the remaining corners of the earth until such a time as the powerful wish to usurp the places in the shade also. Usually the only hope of the ultimate survival of such oppressed species depends upon their powers of adaptation. Thus run the histories of the survival of the fittest, the one proving its fitness by remaining in the sunshine thereby accelerating its development, but curtailing its life, and the other proving its strength by continuing its existence in spite of tremendous opposition. One man's meat is another man's poison; one bee's sunshine is another bee's death.

We eagerly await further developments in this competition, but at present we cannot forgo the temptation to speculate upon it. Will the white-banded bees, thus hard pressed, be finally exterminated? If so, what will be the effect upon *Anthophora* in return? Perhaps by that time they will have become so strong that, like the oak and the ivy, they will be able to carry on prosperously the work of the mining-bees and also maintain the various parasites without seriously feeling the strain. But again, if this happens, what will become of those later parasites which depended upon the white-banded bees, etc., those which, in fact, have killed the goose that laid the golden eggs? They will be compelled either to change their mode of living in some way, to migrate and perhaps perish in the attempt, or to quit living. If, however, the parasitic Diptera adhere to their tendency to confine themselves to sunny areas, and if at the same time the white-banded bees can adapt themselves to their dim corners where they have taken refuge, there is a possibility that the white-banded bees may again increase and at some time regain prestige. Of course, these last sentences are merely speculative, and yet it is by precisely such cat and mouse methods as these that nature lets her many species run on in constant and deadly competition.

(c) Relation to cold, cloudiness, darkness.

Up with the early morning sun, at 6:30 in fine weather the mining-bees of all three species, the carpenter-bees and the *Monobia* mud wasps were all heartily at work. They began early and worked diligently while the sun shone and then relaxed soon after midday as soon as the bank was in the full shadow. I have said elsewhere that these insects know no calendar but the thermometer; again we might well say they know no clock but the sunlight. I hope some day to find out just what is these bees' program of daily work when their nests are in the normal light, i. e. not shaded by artificial structures during any part of the normal hours of sunlight.

While the action described above was their usual program, they sometimes made exceptions to this habit. These digressions I have been unable satisfactorily to explain. Often during the early part of June the *Anthophora* bees were seen at work at 5:30 a. m., and continued busy until sunset. Despite the fact that May 28 was cloudy, some 20 mothers were actively engaged in carrying in orange-colored pollen. On the other hand, when on June 16 the temperature dropped twenty degrees, their activities were greatly lessened, and they did not venture out to resume their work until 9 o'clock on the 17th. Also after cold nights or rainy mornings and toward the end of the season, even when the sun did shine, often they did not come out early, but waited until the bank was thoroughly warmed up. Sometimes, when a run of cold days came in early autumn (in this detail I am speaking of the white-banded bees), they did not get out to work for two or three days; suddenly they seemed to be seized by the impulse to work, and then they would come out even on cold and gloomy days and work hard, striving to complete their task almost as if they felt in some way that time and life were ebbing fast.

It will perhaps lead to a clearer understanding if we pass from these generalizations to the record of what actually happened after the rainy afternoon of August 29 and other cloudy and cold days. I merely give excerpts from the original notes.

"August 30. The rain fell until 2 p. m. yesterday, after that hour no insects were abroad. The night was rather cold and today it was 10 a. m. before the first insect appeared about the bank. A black cricket poked his head out of one of the bee-holes where he had spent the night. Soon several wasps, *Tachysphex terminatus*, were scraping away the soil about their nests. A few specimens each of *Ancistrocerus fulvipes, Monobia quadridens* and *Xylocopa virginica,* and one each of *Trypoxylon clavatum, Chlorion auripes,* and three white-banded bees, *Entechnia taurea* were at work at their various duties of nidification: these were all observed at 11:30 a. m. and all seemed unusually industrious, as if to make up for the time lost in yesterday's rain. As it neared noon, the white-banded bees appeared in greater abundance, and the parasitic bee-fly, *Argyromoeba tigrina,* made its appearance. That the sunshine was a factor in bringing out the bees is evidenced by the fact that only from the nests that had been warmed by the direct sunlight had the bees crept out to work. The mothers from the nests in sunny sites were the first to be active in bringing loads of pollen, while those nests not so favored showed no external signs of life. I have previously stated that this species of bee, *Entechnia* *taurea,* will burrow without regard to the light, that it chooses dark areas as well as well-lighted ones without any apparent detriment to the work, but here it is apparent how, especially after a cold night, the sun indirectly influenced the amount of work done by warming up the nest and routing the sleepers. After all we must admit, that despite the fact that these bees often built their nests back in the shadow of the porch, they seldom did work when the sun had passed beyond the zenith, leaving the bank more shaded. It is interesting to note that in the afternoon, after the deeper shadows fell upon the bank at about 2 p. m. the activities of several species were at their minimum. An analogous condition existed on dark or cloudy days. The insects behaved much as the population of a normal site would at twilight. As the shadows lengthened, some spiders would become active, thus adding the suggestion of night-prowlers to the twilight setting.

"September 4. While I have elsewhere recorded that as the sun warms up the bank, more and more of the *Entechina* bees come out of their holes and begin work, it is now my pleasant duty to record that this rule is not absolute, for today the behavior is reversed. Yesterday they were working intensely at their digging; now it is dull and dreary after the heavy rain in the night, yet the bees have been busily at work carrying in pollen. In so far as I can see, this reversal of behavior can be due only to the fact that much rainy weather lately has caused a set-back in their work, and they begin to 'realize' that if ever they are going to get their domestic duties done before Gabriel sounds his trumpet, they will have to be up and doing despite weather conditions.

"September 12. The last two or three nights have been very cold and today at 9:45 the only life about the bank is a lone *Tachysphex terminatus*, an unfortunate caterpillar in the jaws of an ant-lion, and about ten gray lizards. None of the white banded females are in evidence, but in the garden back of the house, eight males were this morning found huddled in the cups of as many wild bindweed blossoms where they had spent the night. The flowers had not closed, evidently because of the low temperature, and these male bees found lodging there all night, and even at ten o'clock in the forenoon, they were in a torpid and lethargic condition, heavily laden with dew. This discovery so late in the season also shows that they are not shorter-lived than the females as we have found for other wasps and bees. By noon the bank has warmed up perceptibly, and a few of the sun-loving insects are out; one *Entechnia taurea* hovers over her nest; one cuckoo-bee, *Chrysis coeruleus* lurks suspiciously about. At two o'clock the first carpenter-bee, *Xylocopa virginica,* and an *Ancistrocerus fulvipes* are diligently caring for their nests. It is 3 p. m. before the first carpenter mud-wasp, *Monobia quadridens,* becomes active about the wood tunnels overhead, and even the Chalcid parasites, *Monodontomerus sp.* linger to this late date. These meager numbers of each species are no doubt indicative of the entire population at this time of the year. It is interesting, too, to note that despite the fact that most of the activities have heretofore ceased somewhere about two in the afternoon, we now find these remaining mothers working far into the late hours of the afternoon. The day is too short for them; they have their tasks and are intent upon finishing them, and in such stress are not guided absolutely and blindly by instinct, yet they do modify their behavior according to their needs. Whether the sunshine is likewise warming the lizards, or whether the appearance of possible food excites them, I do not know, but at any event these vertebrates, heretofore sluggish, become animated and active at the same time as the remainder of the inhabitants.

"September 23. Only a few stragglers representing some of the more important groups of the inhabitants, remain at this late date, and they are indeed few in number. It is evident that the cold of autumn is a factor in reducing their numbers, but we should like to determine precisely to what extent this is the determining factor, or in how far the weather conditions directly influence their longevity. If the optimum conditions for their existence prevailed for several months longer, it might retard but would not abolish their mortality. In other words, to what extent is longevity inherent in the organism, and how far is death due to some external calamity?

"October 3. Today the most of the few individuals to be seen certainly give one the impression that they have outlived their allotted time—'yet is their strength labor—and sorrow.' Three survivors of *E. taurea* linger helplessly about, as if they had been overlooked by death and did not know how to conduct themselves in the land of the living, where they no longer belong. Indeed no activity is now possible for them, because the flowers from which they have gathered pollen are long since withered. Two *Ancistrocerus fulvipes* mothers are feebly finishing the closure of their nests. Two or three *Monobia* mud-wasps are seen on the rafters above the bank, stunned and half dead with the cold. The only inhabitant showing any semblance to normal activity is the grass-carrying wasp, *Chlorion auripes.* Four mothers have been busy all this dull, gray day carrying in blades of grass to plug up their nests in the old burrows of the carpenter-bees. All the creatures of the unit are now practically ready for their long winter sleep. Soon the bank, frozen or snow-covered, will look utterly barren and lifeless, yet within that mass of earth is life —potential life that in the warm days of spring will burst forth with renewed vigor, ready to battle again in sharp competition for the possession of a small portion of the earth which they may call home.''

With the approach of cold weather the carpenter-bees crowd into their tunnels and quietly await death. This I suspected one spring when I opened a nest in a piece of wood which contained six adults, all dead. During cold days they often remain in the cells, crowded close together, and come out again when the day grows warmer. I have seen them come out for a little while as late as October 13. On another occasion in early September, I watched in vain for two days, for the occupants of a nest. Concluding at length that they had joined the heavenly choir, I proceeded to investigate with an ax. At the first blow, a loud chorus of buzzing greeted me, and then one by one twelve bees, each angrier than the last, flew out of the tunnel. This startling experience made me wonder if it is not possible that part if not all of them, hibernate in this way instead of dying with the first cold of autumn. It seems to me that in mild winters or in the southern states they might easily hibernate thus.

There is some evidence that the clearness of the light may be a factor in the homing behavior of the mining-bees. When they returned from the field on their regular day trips, each tumbled precipitously into its own hole without exploring the region or seldom trying out any of the burrows before finding its own. (Figs. 1 and 4 show how similar and how close together the burrows were). But one evening between 7 and 7:30, when it was almost dark and bees were returning home, many hesitated and hovered about before the colony and even entered several holes before finding their own. Two factors may enter into this inability to find their hole, viz., the condition of weariness and the failing light. This seems to us a logical foregone conclusion, and it would be quite superfluous to mention it except for the fact that a certain school of investigators argue for a sixth sense to serve these Hymenoptera in their homing flight or the ability to return home as if by magic.

(d) Relation to rain.

All of the mining bees carried water for their excavating. Rain helped them substantially by filling the wagon-ruts in the road and giving them a supply of water nearby. When these puddles dried up, they were obliged to go a long way for water, and in some cases they did without water or stretched a gulletful over so much earth in the burrow that the result was not plastic mud that could be shaped into turrets, but crumbly, slightly moist pellets that could only be kicked out of the hole.

The bees did not leave their burrows during a rainy spell, and I have never yet seen a mining-bee return to the nest during a storm. I did, however, watch five *Monobia* mud-wasps come home during a heavy downpour. They came in at intervals, all dripping wet and slow of flight, and crept into their holes. The carpenter-bees nesting in the same place did not come home during the storm. They saved themselves a drenching, and after an hour or so, when the storm had ceased, they came flying blithely in. We have recorded elsewhere in these pages that the rain drops on the leaves near by were eagerly lapped up by *A. abrupta* and used in their work of excavating, and I should not be surprised if drops of dew in the early morning were gathered for the same purpose.

While we find evidence of a certain amount of destruction of life by rainstorms, insects of a great variety beaten down by the rain, and their nests in the earth cut open or buried deeply by the erosion of the soil, yet the rain is not without its benefits also. It has been noticed that immediately after a rain following a long dry period, there was a surprising increase in the population of burrowing Hymenoptera. For a time I cast this aside as mere coincidence, until the evidence seemed too strong to be thus discarded. Why this sudden appearance after the rain, and what is the direct action of the rain upon their emergence? There is no physiological connection, I am sure, but merely a physical relation. During a period of drought the earth had become extremely hard; hence the emergence of these young ground-dwellers was rendered impossible. Perhaps they could wait for a time, but surely not for long. We have no way of knowing how many or what proportion of them perished in their futile attempts to break through the brick-like earth. The rain came and softened the earth, and lo! they appeared as if by magic. No doubt there was heavy elimination here, but in this case one cannot call it the survival of the fittest; it was only the survival of the lucky, and how do we know but the lucky ones in this case may have been the least fit to perpetuate the race? In the activities of the turret-building bees also, we find wet or dry weather an important factor in their nest building. In dry years, the turrets are almost entirely omitted and in the case of *A. abrupta,* when for the scarcity of water, much labor is put into hard digging, the number of young is diminished.

(e) Relation of inhabitants to plant life.

At first thought, one sees but little relation between the plant and the animal life of the bank. The vegetation about the base of the bank, scanty as it was, harbored numerous insects, such as small beetles, beetle larvae and caterpillars, which sometimes dropped into the ant lion pits. The grass-carrier wasp gathered grass for her nest; the mining bee, the carpenter bee and the *Halictus* went to the plants for nectar and pollen. The caterpillar wasps *A. fulvipes* visited the plants for their nectar and their caterpillars; the *Trypoxylon* and the *Tachysphex* wasps went to the vegetation for their spiders and grasshoppers respectively. As we have related before, the flowers of the wild morning glory served so well as bachelor quarters for the males of the white-banded bee that the females were obliged to fight for even a chance to harvest the pollen from the flowers. The bees came in from the surrounding vegetation bringing pollen of various colors—yellow, orange, white, or light green. One often found against the side of the bank splashes of this pollen which had been lost in their homeward flight.

For some time I suspected an intimate correlation between the dates of the persimmon blossoms and the emergence of the *Anthophora* bees. In the spring of

1920, I watched to compare the dates. A large number of *Anthophora abrupta* pupae which had been brought into the laboratory early in April gave forth their young in May;* the males emerged from May 10 to 25 and the females only from May 22 to 25. On May 27, I visited Wickes and found both sexes abundant about the clay bank; this indicates that the time of emergence for the controls in the laboratory was about the same as those out-of-doors. Previously I had recorded the coincident dying off of these bees with the dropping off of the persimmon blossoms, from which they gathered their pollen and food. On May 27, I visited the permisson tree near their colony, and found it laden with large buds, but no insects were about the tree. The next morning, several branches bore flowers; and lo! dozens of *Anthophora* bees were already present, joyously busy about the new blossoms.

While this may at first seem to be only coincidence, or to show that the bees had simply turned to any flowers that they could find, we should not be hasty in dubbing it mere chance until we have given due consideration to the fact that the benefits of the association of blossoms and bees may be mutual, and may be of as great importance to the one as to the other, or until we have more data on these interrelations.

(f) Death by violence, and natural death.

To eat and to be eaten seems to be the law of the wild. In the interrelation of life in the clay bank, we have repeatedly noticed how one insect falls prey to another. We seldom think of natural death among the insects,

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*Trans. Acad. Science St. Louis, 24:35, 1922.

but this, too, occurs, and often to a much greater extent than we usually suspect. During this study at the bank, I have often picked up dead and enfeebled insects. Not all the Chalcids fell prey to the spiders and ant lions; I have removed hundreds from the crevices where they had crept in to die. Many mining-bees were picked up dead or limp at the end of their season and many more were pulled out of their burrows. The cuckoo-bees were picked up dead, too—and what enemy could wound a cuckoo-bee in its thick armor? The blister-beetles, *Epicauta marginata,* dropped dead from the plants near the base of the bank. Others found there whose death was not accounted for, were *Harpalus dichrous* Dejean (E. A. Schwarz), *Tachysphex terminatus, Trypoxylon sp., Pseudagenia mellipes, Halictus pectinatus, Anthophora,* and *Xylocopa virginica.* Thousands of dead Chalcid parasites were found in the burrows when they were examined during the winter.

One often found newly dead female bees at the foot of the bank. This was very puzzling, until one day I actually saw where lay the trouble. A returning female *A. abrupta* found that during her absence another bee of the same species had appropriated her nest. A fight ensued, in which the usurper was thrown bodily to the ground and after a few twitches of the legs was dead. Other fights of a less serious nature were often observed. On one occasion I saw a female with part of her body protruding from the burrow. I pulled her out with the forceps, and found her tenaciously clinging with her jaws to a second female that had evidently intruded in the burrow. The next day also I saw the yellow, pollen-laden legs protruding from a bee which seemed to be in agony. I pulled it out with the forceps, and it, too, pugnaciously clung to another bee, which had evidently taken advantage of the owner's absence to usurp her home.

(g) Relation to Soil conditions.

Not all of the soil that came out of the burrows went into the making of the turrets. Much of it was kicked out and fell on the ground below. This was neither dust nor pellets, but characteristic minute bits or granules. A very considerable heap of these granules had accumulated in front of the center of the bank, where the greatest activity occurred. This strip of drift measured 70 inches in length, 6 inches wide and from ½ to 2½ inches in depth. This of course gave the *Tachysphex terminatus* wasps an excellent medium in which to make their nests, and afforded a material which made pit-making for the ant-lions a pleasure.

It seems superfluous to mention the fact that, had the nature of the soil been very different from what it was, the colony of insects, especially the principal characters, the mining-bees, would never have been there, since a firm, clayey soil of this nature is quite essential to masonry of their kind; and too, if these pioneers had not thrown out a large mass of granular soil to the bottom of the bank, there would have been no ant lions, for these never dig pits in firm soil.

(D) CONCLUDING REMARKS.

After following the great things and the little things in the lives of these tiny creatures, we may actually compare the whole to a play upon the stage. The environment corresponds to the stage; the dominant members correspond to the leading characters, the secondary species to the essential but subordinate characters. The individual animals adjust themselves to one another, and to the environment, as the personalities in the play adjust themselves to one another and to the conditions. "In both groups some individuals are dominant, some used and useful, some are tolerated, some pick up the crumbs, still others are predatory or parasitic, and all must be mutually adjusted to one another and to the environment."

On this little stage of the clay bank we have seen enacted the tragedies and joys of life and love, birth and death of many creatures; their tolerance of, or indifference to one another, their craftiness in preying upon one another and their alertness in escaping persecution, the artisans at work, the visitors and the varying outcome of their visits—all these things and many others pertaining to the lives of a hundred insect species for a day, a season, or a succession of years.

We have seen the pioneers blazing the trail, the renters following hard by, and the parasites ever on hand keeping in check the otherwise rapidly increasing races; we have seen some that are transitory and some that visit, prefer to remain, and may prove either a benefit or a burden to the group.

And finally we have seen their behavior toward the elements of nature, to sunlight and cold, to darkness and to rain; all these little creatures would come and go, act and react, conscious or unconscious of one another and of the environment. All of the relations and interrelations which have controlled them, and all of the influence which they have wielded upon each other, to bring this social unit to the degree of development or balance in which we find it in the present years of the study, must have occurred within a short period, for the existence of the clay bank covered less than a score of years. How many bee kingdoms or families have grown, lived and crumbled to oblivion here in that time, we have no way of knowing. Under our very eyes we have seen one grow to an unwieldy size at the expense of another that has almost crumbled to decay.

It may seem naïve for us to inquire into the meaning of all the little commonplace phenomena which we have observed here, and to search for many more not yet observed. A casual reader might say "*Of course* the organisms adjust themselves to each other and to their environment; why all this fuss about it?" Perhaps the same casual observer would have said to Isaac Newton "*Of course* the apple will fall; why ask questions about it?" And yet while we glibly call the phenomena commonplace, we must admit that we really know so little about the vital points in the lives of these organisms in this one microcosm that if we were to attempt to modify the balance of the population there we should bungle the delicate adjustments so that our experiments would not end anywhere near the point where we aimed; and until we can thus direct the controlling factors, we cannot boast an understanding of the subject.

"Every reflective biologist must know that no living being is self-sufficient, or would be what it is, or be at all, if it were not part of the natural world, although no truth is easier to lose sight of." W. D. BROOKS.

EXPLANATION OF PLATE

Plate XIV

Fig. 1. The work of *Anthophora abrupta*. Not all of the excavated soil went into turret building, but much of it was kicked out, and formed at the base (x) a medium for the habitat of ant-lion larvæ.

Fig. 2. The clay bank under the porch.

FIG. 1

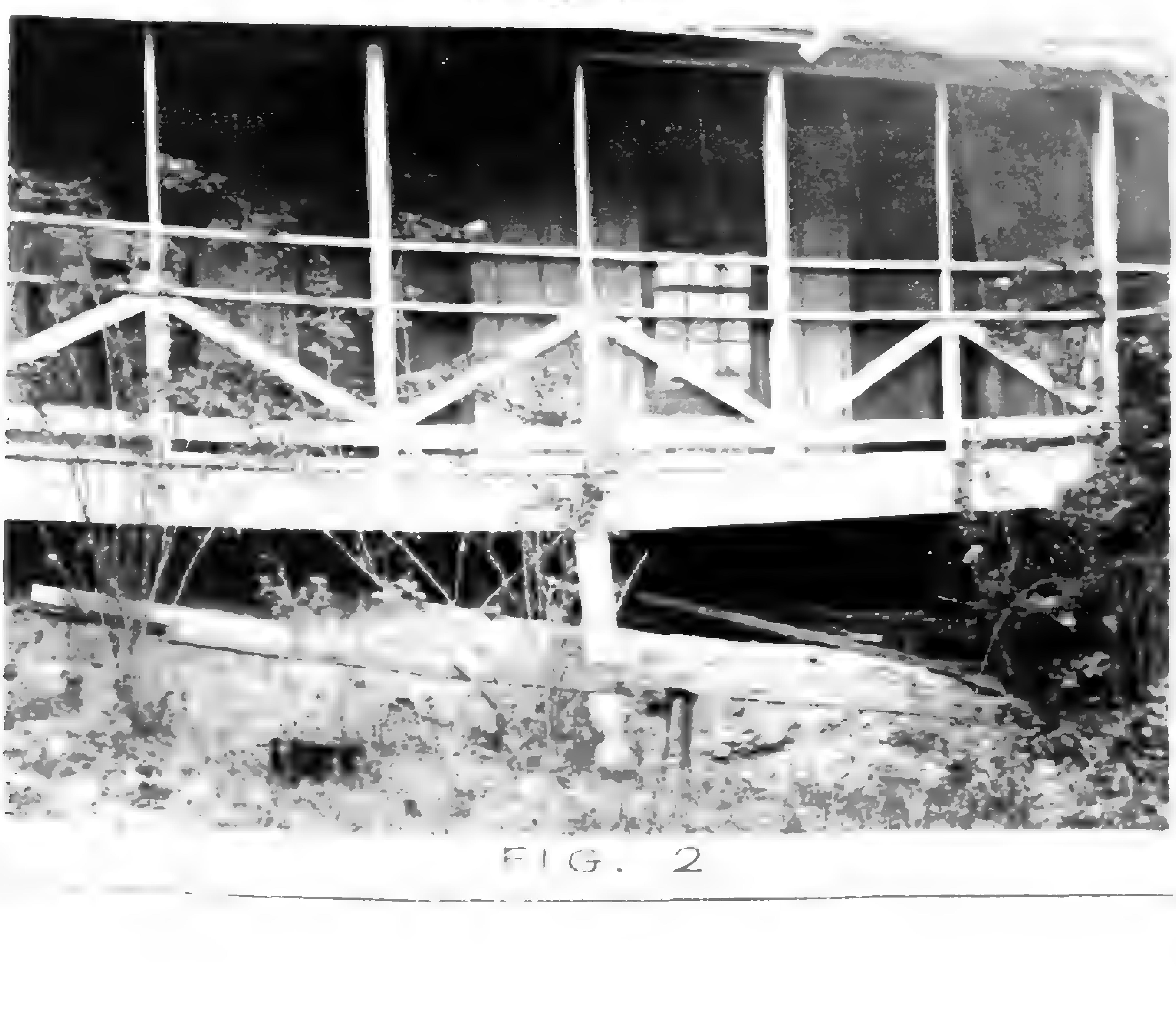

FIG. 2

EXPLANATION OF PLATE

Plate XV

Fig. 3. The south-half of the clay bank. Note the absence of burrows in contrast with figure 4.

Fig. 4. The north-half of the clay bank.

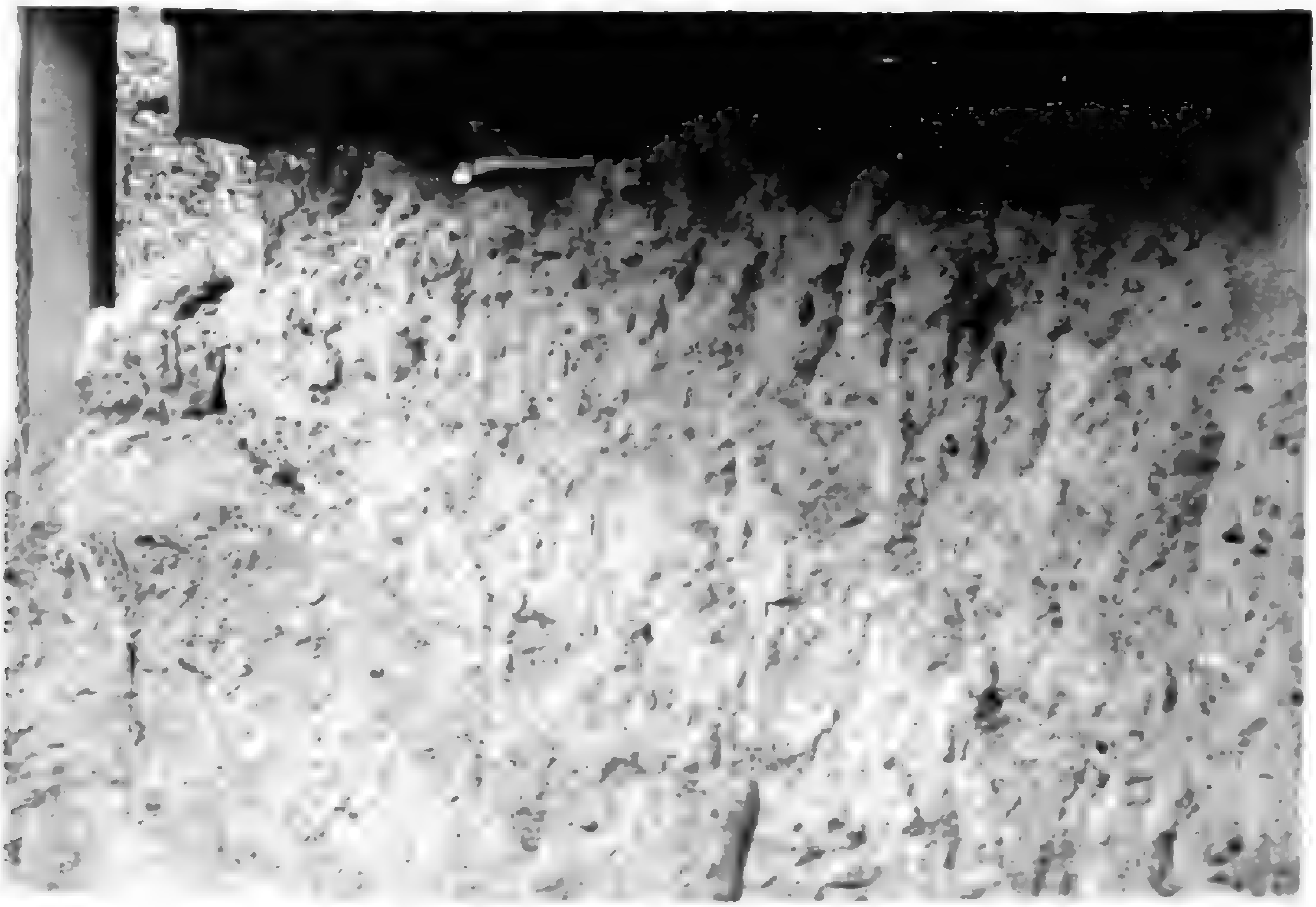

FIG. 3

FIG. 4

EXPLANATION OF PLATE

PLATE XVI

Fig. 5. The mining-bee, *Anthophora abrupta*, (2 x natural size).

Fig. 6. The mining-bee, *Anthophora raui*, (2 x natural size).

Fig. 7. The white banded bee, *Entechnia taurea*, (2 x natural size).

FIG. 5

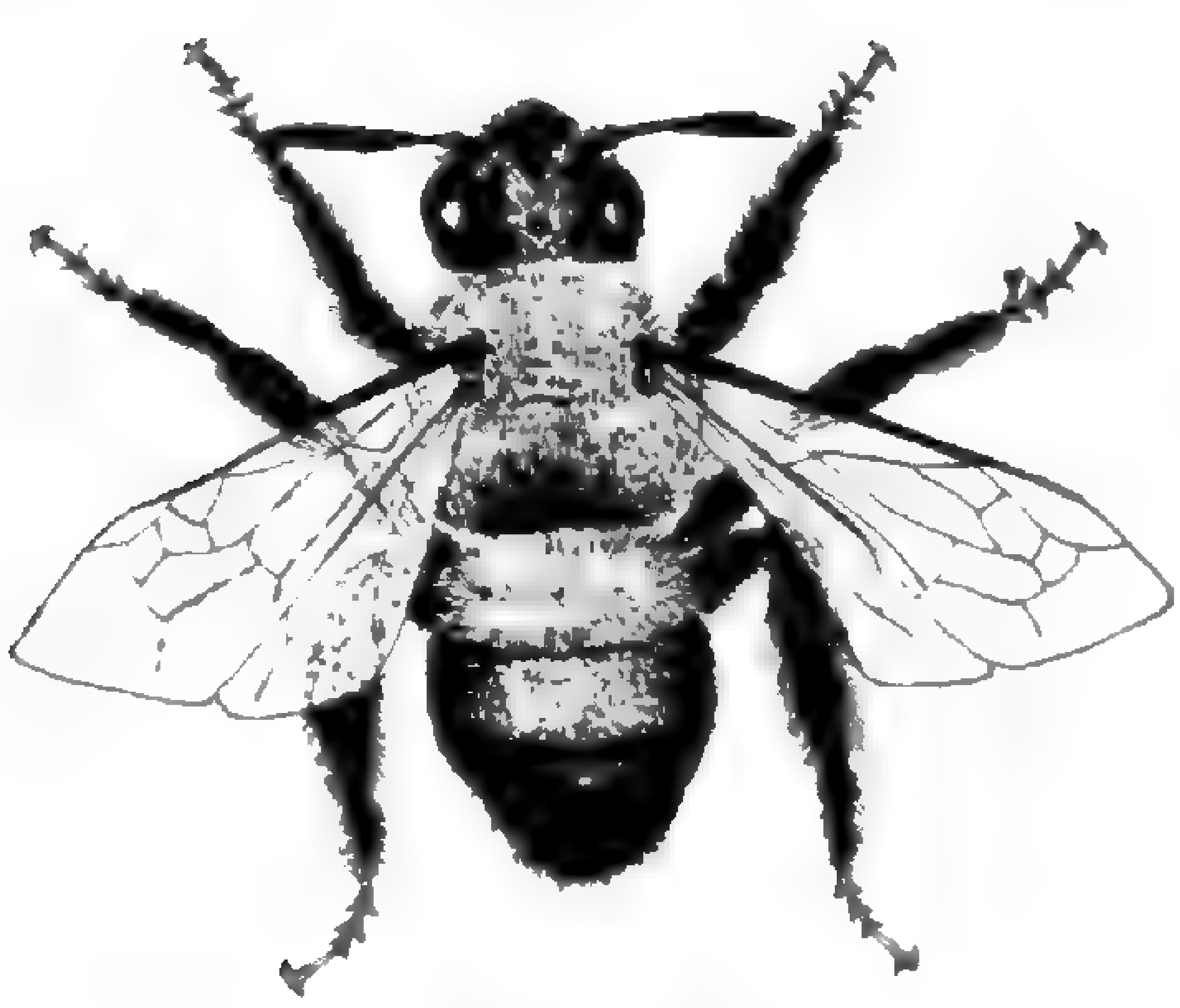

FIG. 6

FIG. 7

EXPLANATION OF PLATE

PLATE XVII

Fig. 8. The "Ham and Bud" club. Note the clay bank under the south-half of the porch.

FIG. 8

EXPLANATION OF PLATE

Plate XVIII

Fig. 9. The turrets of mining-bees. E, *Entechnia taurea;* arrow, *Anthophora raui.*

Fig. 10. The upturned turrets of *Anthophora raui.* (A wad of cotton was placed in the opening of each turret to show its up-turned position.)

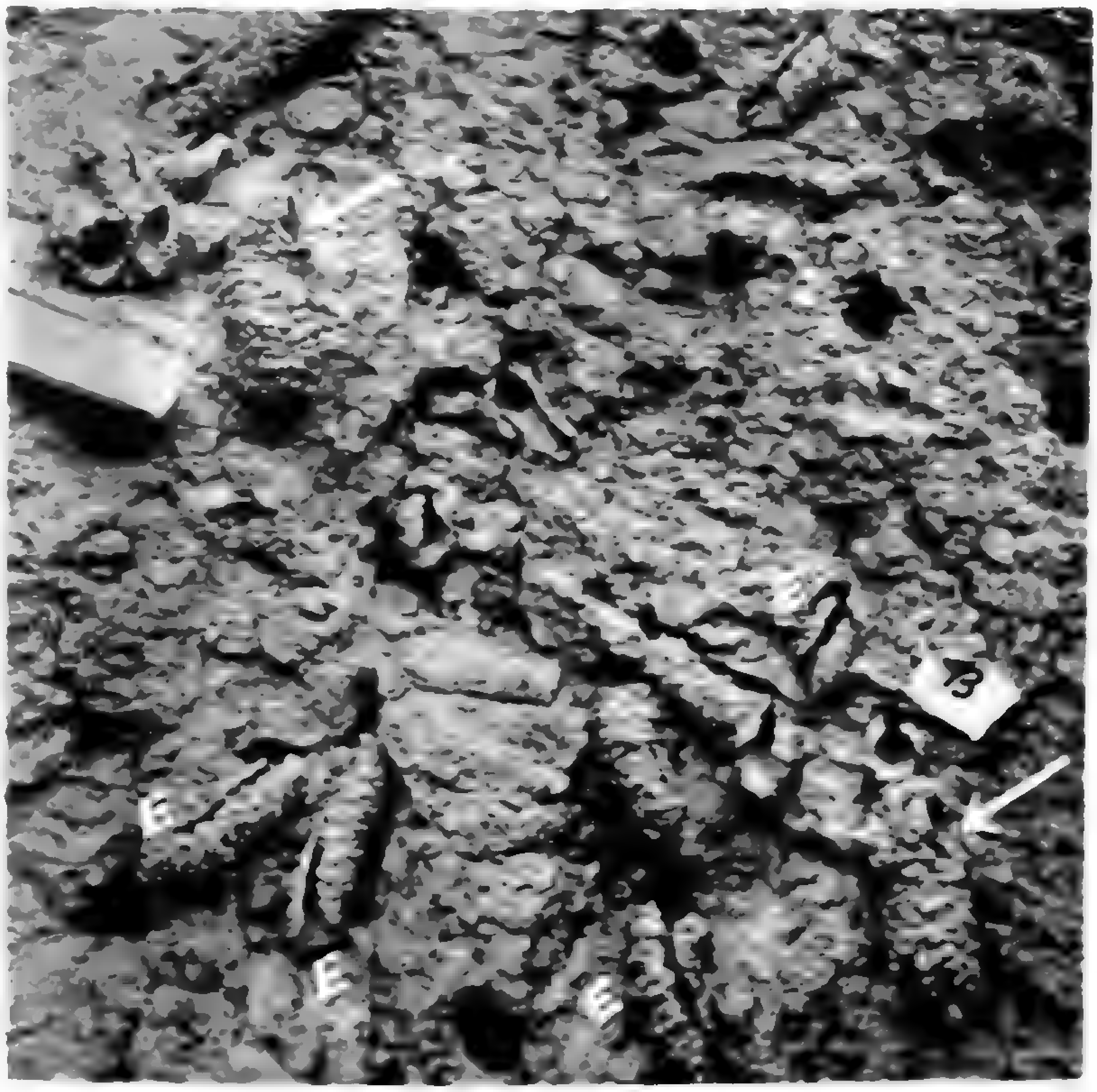

FIG. 9

FIG. 10

EXPLANATION OF PLATE

Plate XIX

Fig. 11. The Cells of *Anthophora raui.*

Fig. 12. The pupæ of *Anthophora raui.*

Fig. 13. A portion of the tunnel, and the orifice of the nest of ***Halictus** zephyrus.*

Fig. 14. Nymphs of *Chortophaga viridfasciata.*

Fig. 15. Ant-lion pits in the dust at the foot of the bank.

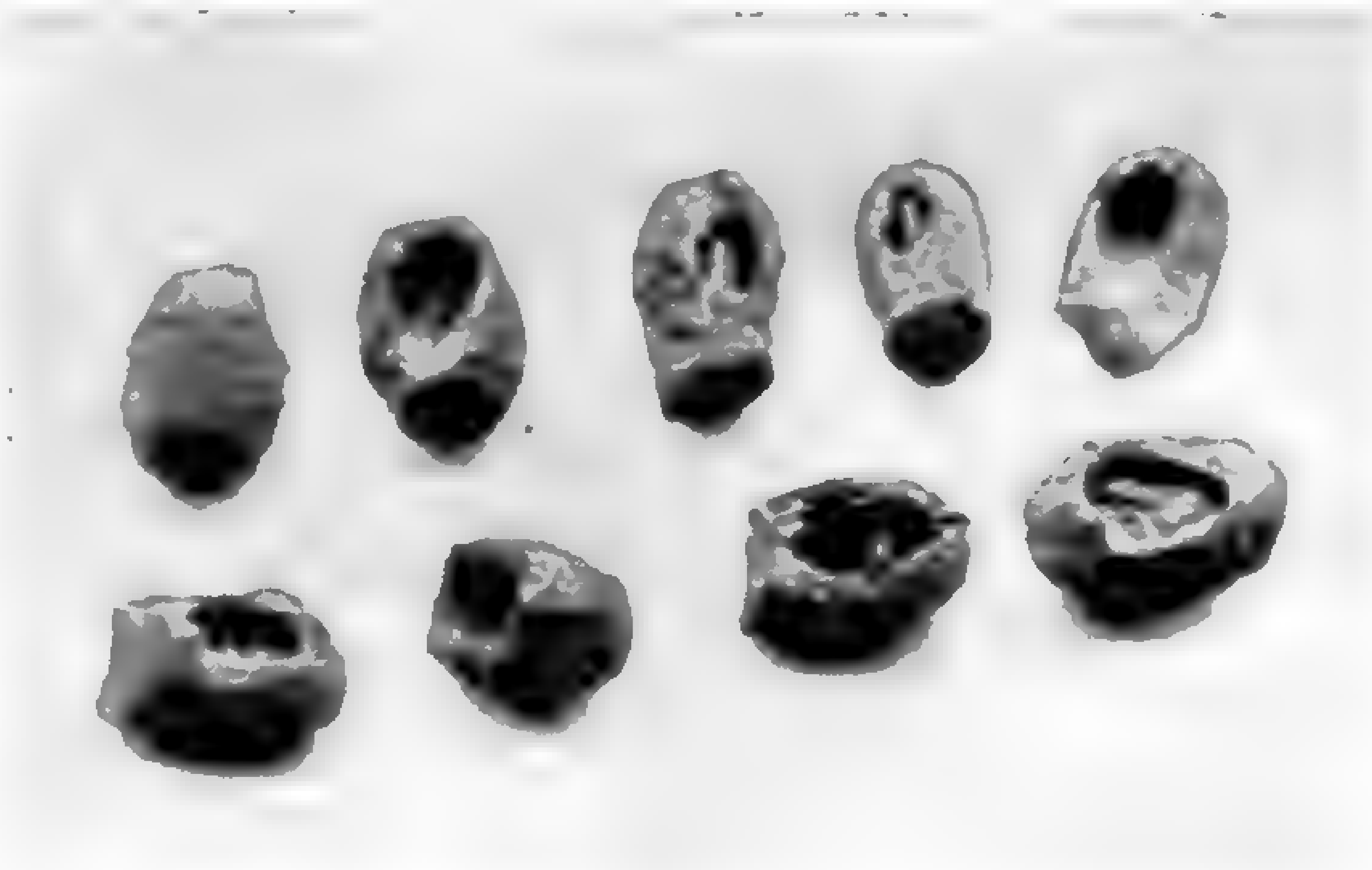

FIG. 11

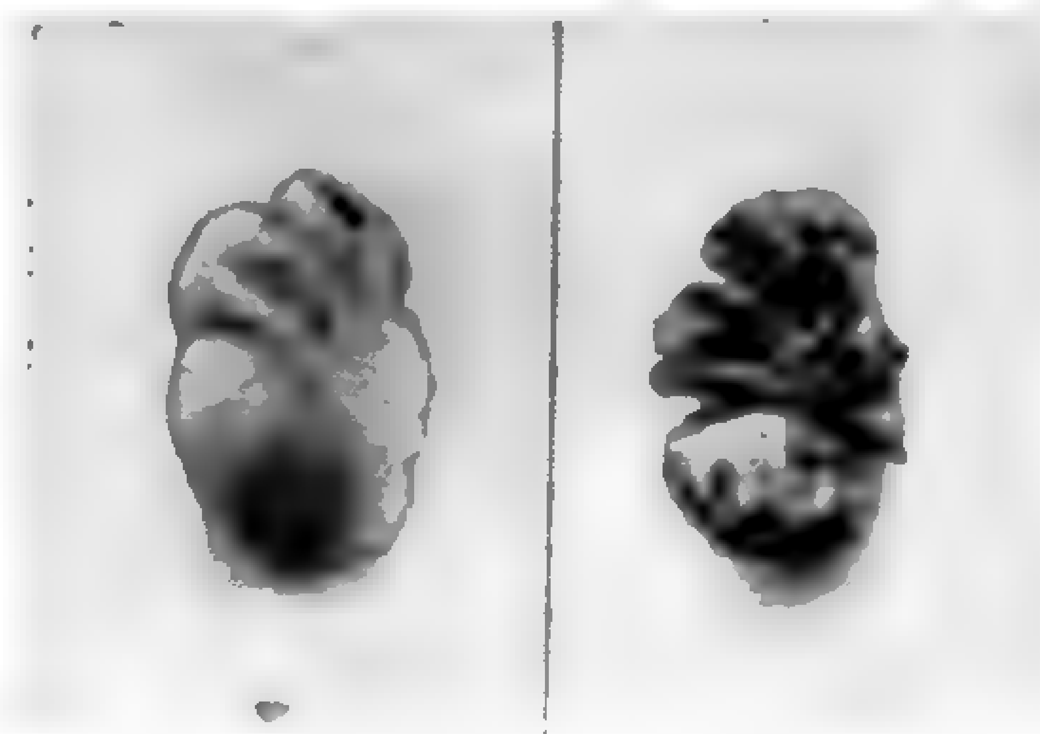

FIG. 12

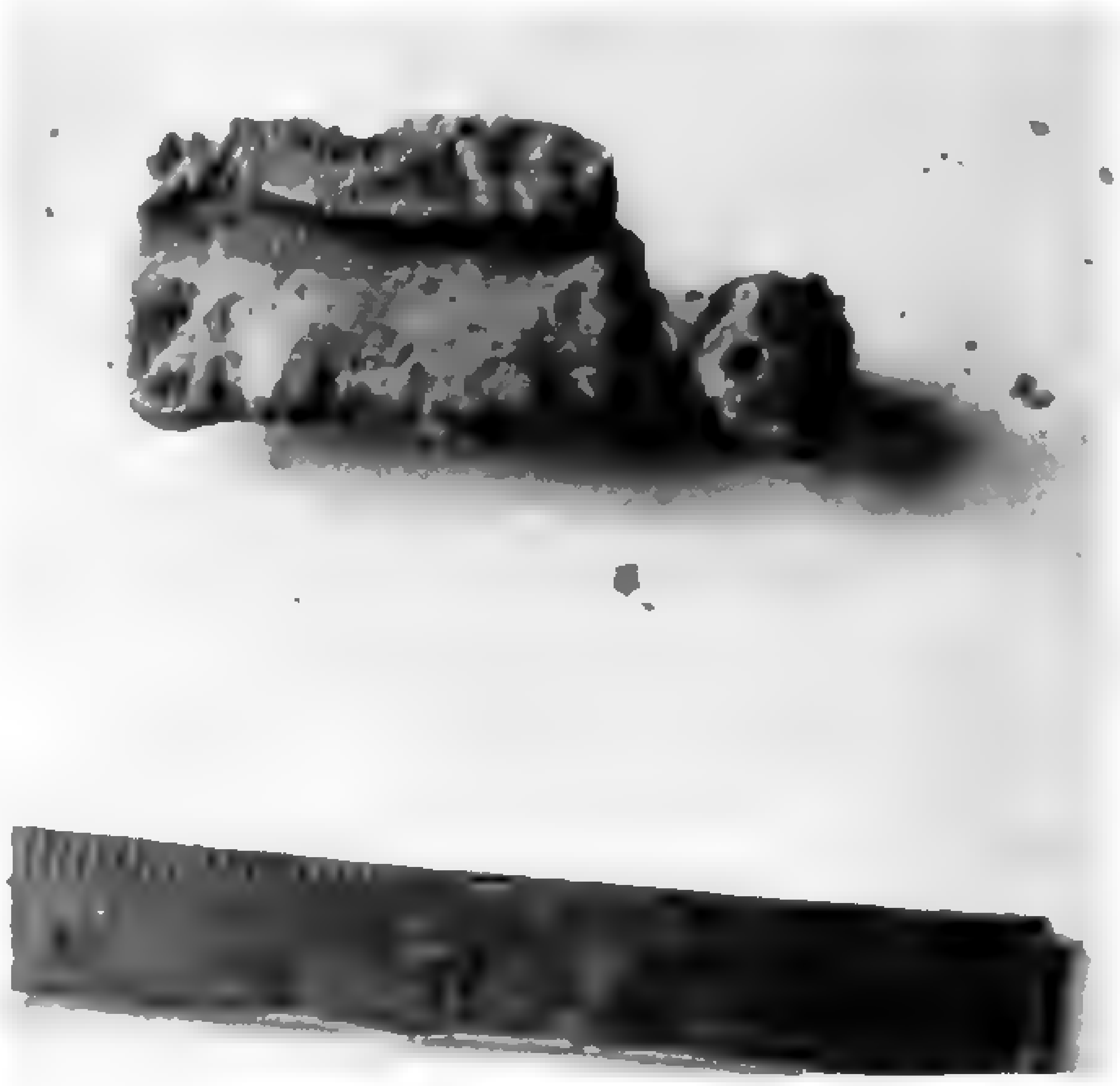

FIG. 13

FIG. 14

FIG. 15

EXPLANATION OF PLATE

Plate XX

Fig. 16. A conspicuous inhabitant of the bank.

Fig. 17. Gray lizards inhabited the bank.

Fig. 18. Silver winged fly, *Argyromoeba tigrina*, (2 x natural size).

Fig. 19. The shedding skins of *Argyromoeba tigrina*.

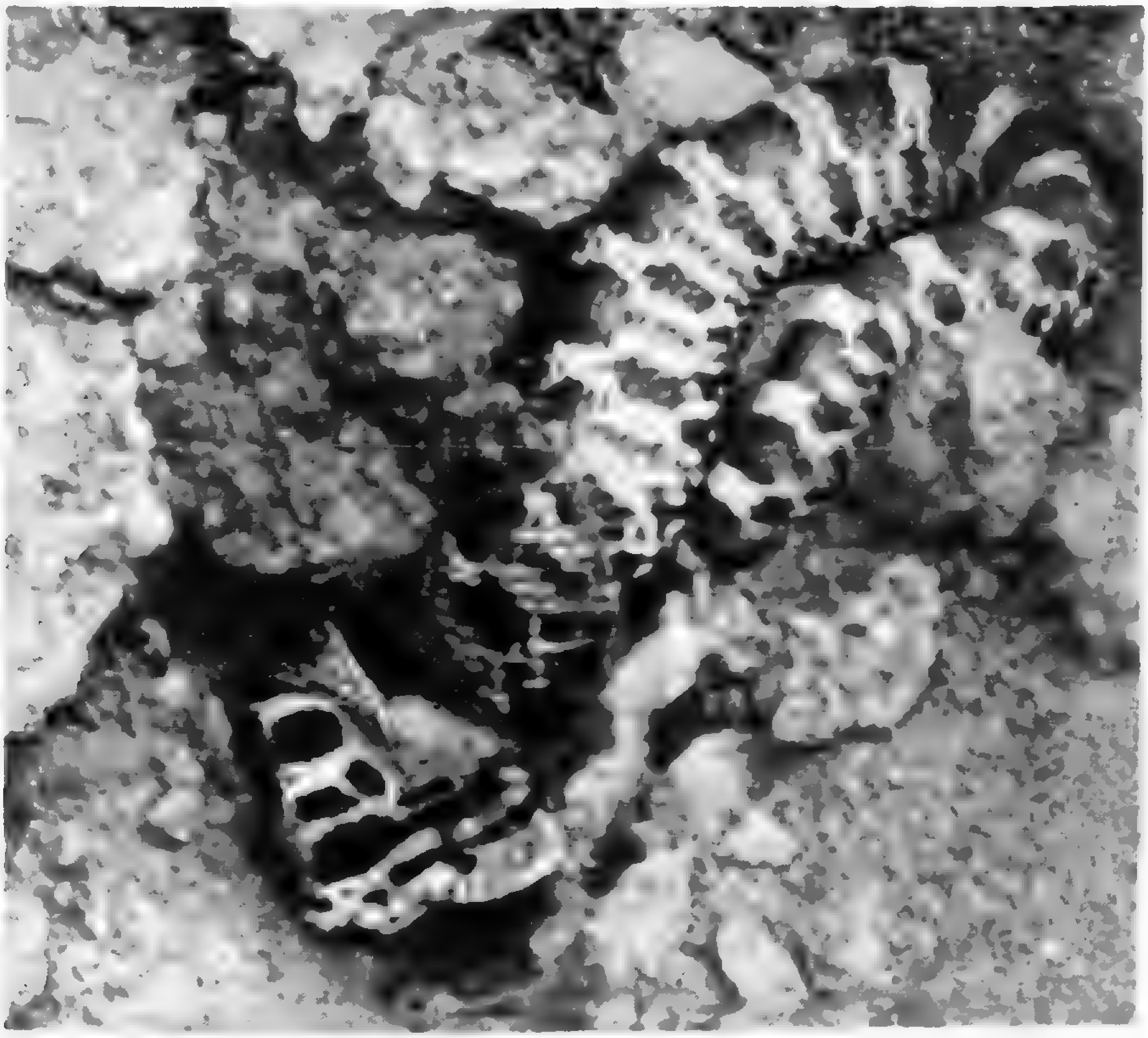

FIG. 16

FIG. 17

FIG. 18

FIG. 19

EXPLANATION OF PLATE

Plate XXI

Fig. 20. A portion of the face of the clay bank, showing turrets of (E) *Entechnia taurea*, and (U) *Anthophora abrupta*. (This shows the relative size of the turrets of the two species.)

Fig. 21. The turrets horizontally made (E) of *Entechnia taurea*. (S) The upturned turrets of *Anthophora raui*.

Fig. 22. Three years later; the same area as Fig 3; the nests of *A. abrupta* are gradually spreading southward as the sunlight reaches the previously shaded portions.

FIG. 20

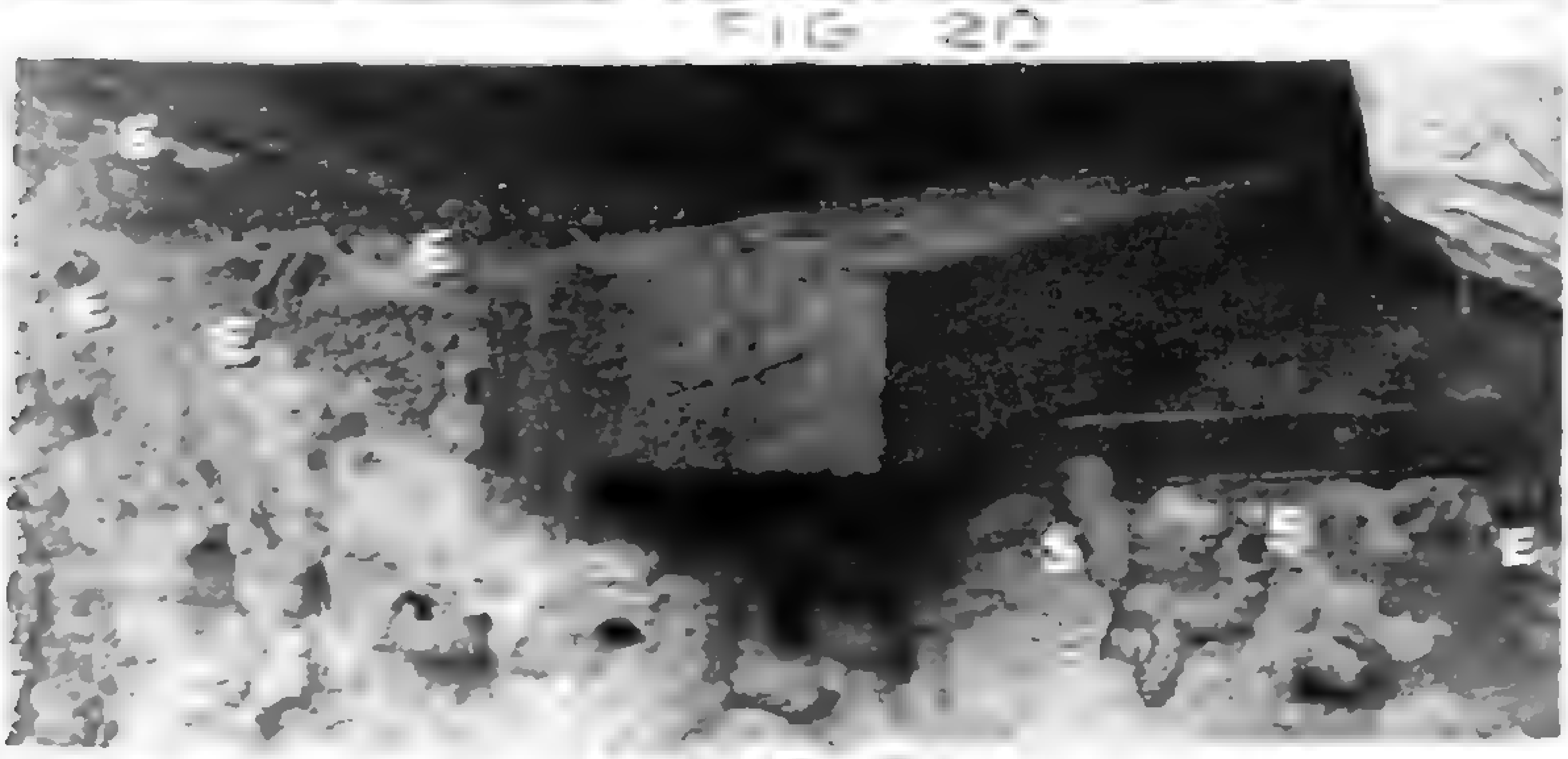

FIG. 21

FIG. 22

Transactions of the Academy of Science of St. Louis

VOLUME XXV—No. 8

FLORIDA FLOWERS AND INSECTS

CHARLES ROBERTSON

Issued September, 1927

FLORIDA FLOWERS AND INSECTS.

CHARLES ROBERTSON.

Except when Orlando is specified, the observations recorded here were made at Inverness. Observations on blooming seasons did not extend beyond April. Flowers indicated as blooming the last of April probably bloomed longer.

SIGNS, ABBREVIATIONS, ETC.

ab = abundant; c = collecting pollen; csp = collecting stray pollen; f = feeding on pollen; fq = frequent; fsp = feeding on stray pollen; gn = gnawing; in cop = in copula; lp = labial palps; Ma = non-social long-tongued bee flower; Mas = social long-tongued bee flower; Mi = non-social short-tongued bee flower; Mis = social short-tongued bee flower; n = non-pollinating; o = ornithophilous; Pol = polytropic; R = red and all dark colors; S = sphingophilous; sc = sucking nectar and collecting pollen; sf = sucking nectar and feeding on pollen; W = white; Y = yellow, greenish to orange; ♂ = male; ♀ = female; ☿ = worker. The family ending "idae" is omitted, as Halict for Halictidae. The months are Ja, F, Mr, Ap, My, Jn, Jl, Au, S, O, N, D.

When no other indications are used after a name, the insect is counted as sucking nectar legitimately and effecting pollination. Dates after "visitors observed" indicate the period within which the observations were made. Signs in parentheses, like "Halictidae (♀, c)" mean that all of the following Halictidae were females and all collecting pollen. Numbers in parentheses, for example (6, 65), refer to the titles and pages in the bibliography. In tables they are for species and visits or individuals. The plant names used here were taken from Small, "Flora of the Southern United States."

GENERAL SYNONYMICAL LIST.

The following is a list of all of the insects taken on flowers, with authors' names which are not repeated in the special lists. Names which occur often enough to justify it are abbreviated as follows: Bs. = Boisduval, Cm. = Cramer, Cq. = Coquillett, Cr. = Cresson, Ed. = Edwards, F. = Fabricius, L. = Linnaeus, Lp. = Lepeletier, Lw. = Loew, Mc. = Macquart, Mg. = Meigen, Rb. = Robertson, Rh. = Rohwer, Ss. = Saussure, Sm. = Smith, Tn. = Townsend, Wd. = Wiedemann, Wk. = Walker, Wl. = Williston. Names in parentheses are the correct ones.

BIRDS.

Trochilidae: Trochilus colubris L.

LONG-TONGUED BEES (30).

Anthophoridae: Centris sp., Emphoropsis floridana Sm.; *Ap.*: Apis mellifera L.; *Bomb.*: Bombias scutellaris Cr., B. separatus Cr., Bombus americanorum F., B. impatiens Har.; *Ceratin.*: Ceratina dupla Say; *Emphor.*: Melitoma taurea Say; *Epeol.*: Epeolus zonatus Sm.; *Eucer.*: Florilegus condignus Cr., Melissodes sp., M. variabilis Rb.; *Megachil.*: Ashmeadiella floridana Rb., *type*, Coelioxqs 8-dentata Say, C. sayi Rb., Diceratosmia conjunctoides Rb., *type*, Lithurgus gibbosus Sm., Megachile floridana Rb., *type*, M. generosa Cr., M. lanuginosa Sm., M. mendica Cr., Sarogaster georgicus Cr.; *Nomad*: Centrias rubicundus Oliv., Cephen fervidus Sm.; *Stelid*: Dianthidium curvatum Sm., D. (Anthidiellum) notatum Latr., D. (A) perplexum Sm.; *Xylocop.*: Xylocopa micans Lp., X. virginica Drury.

SHORT-TONGUED BEES (27).

Andrenidae: Opandrena scutellaris Rb., *type; Collet*: Colletes sp., C. sp., C. americanus Cr., C. distinctus Sm., C. latitarsis Rb., C. thoracicus Sm.; *Halic*: Agapostemon splendens Lp., Augochlora fulgida Sm., A. sumptuosa Sm., Chloralictus apopkensis Rb., *type,* C. ashmeadii Rb., *type,* C. floridanus Rb., *type,* C. longiceps Rb., *type,* C. nymphalis Sm., C. reticulatus Rb., *type,* C. tegularis Rb., Evylaeus nelumbonis Rb., E. pectoralis Sm., Odontalictus capitosus Sm., Oxystoglossa sp., O. austrina Rb., *type,* O. matilda Rb., *type, Panurg*: Perdita obscurata Cr.; *Prosopid*: Prosopis flammipes Rb., *type,* P. floridana Rb., *type,* P. schwartzii Ckll.

OTHER HYMENOPTERA (100)

Bembicidae: Bembix spinolae Lp., Bicyrtes insidiatrix Handlirsch, B. ventralis Say, Microbembex monodonta Say; *Cercer*: Cerceris bicornuta Guerin, C. insolita Cr., C. austrina Fox, *type,* C. rufopicta Sm., C. verticalis Sm.; *Chalcid*: Leucospis affinis Say, L. robertsoni Crawford, *type,* L. slossonae Weld, Orasema sp. Spilochalcis flammeola Cr.; *Chrysid*: Chrysis intricata Brulle, Hedychrum violaceum Brulle, Tetrachrysis venusta Cr.; *Crabron*: Anacrabro robertsoni Rh., *type,* Hypocrabro decemmaculatus Say, Solenius scaber Lp.; *Eumen*: Eumenes fraternus Say, E. smithii Ss., Leionotus apopkensis Rb., *type,* L. arvensis Ss., L. australis Rb., *type,* L. bicornis Rb., *type,* L. bifurcus Rb., *type,* L. boscii Lp., L. floridanus Rb., *type,* L. foraminatus Ss., L. fulvipes Ss., L. fundati formis Rb., *type,* L. histrio Lp., L. histrionalis Rb., L. megaera Lp., L. molestus Ss., L. oculeus Rb., *type,* L. saecularis Ss., L. turpis Ss., Monobia quadridens L., Odynerus erinnys Lp.; *Larr.*: Notogonidea argentata Bv., Tachysphex apicalis Fox, *type,* T. laevifrons Sm., Tachytes aurulentus F., T. breviventris Cr., T. duplicatus Rh., *type,* T. pepticus Say var. floridanus Rh., *type,* T. robertsoni Rh., *type; Nysson:* Nysson aequalis Patton; *Oxybel:* Oxybelus floridanus Rb., *type,* O. fulvipes Rb., *type; Pemphredon:* Psen maculipes Fox, *type; Philanth:* Philanthus carolinensis Banks, P. eurynome Fox, P. ventilabris F.; *Pompil:* Allocyphonyx maurus Cr., Anoplius illinoensis Rb., Aporinellus fasciatus Sm., Arachnoproctonus ferrugineus Say, Ceropales robinsonii Cr., Episyron biguttatus F., E. posterus Fox, *type,* Lophopompilus philadelphicus Lp., Planiceps calcaratus Fox, *type,* P. dubius Fox, *type,* P. minor Fox, *type,* Poecilopompilus navus Cr., Pompiloides americanus Bv., P. argenteus Cr., P. marginatus Say, P. subviolaceus Cr., P. tropicus L., Psammochares tenebrosus Cr., Sericopompilus plutonis Banks; *Sphec.:* Chalybion caeruleum L., Isodontia cinerea Fern., I. exornata Fern., Priononyx thomae F., Psammophila violaceipennis Lp., Sphex gracilis Lp., S. nigricans Dahlbom, S. pictipennis Walsh, S. procera Klug, S. vulgaris Cr.; *Scoli:* Campsomeris plumipes Dru., C. quadrinotata F., Discolia nobilitata F., Elis floridanus Rh., *type,* E. propodialis Rh., *type,* E. robertsoni Rh., *type; Tenthredin:* Pseudosiobla robusta Kby.; *Tiphi:* Tiphia floridana Rb., *type,* T. vulgaris Rb.; *Vesp:* Polistes americanus F., P. pallipes Lp., P. rubiginosus Lp., Vespula maculata L.; *Vipion:* Cardiocheiles nigriceps Viereck, Microbracon vernoniae Ash.

DIPTERA (104).

Agromyzidae: Milichia indecora Lw., M. robertsonii Cq., *type,* Milichiella arcuata Lw.; *Anthomy:* Bithoracochaeta leucoprocta Wd., Coenosia ovata Stein., C. sexnotata Mg., Homalomyia prostrata Rossi, Limnophora narona Wk., Phorbia platura Mg.; *Bibion:* Dilophus orbatus Say; *Bombyli:* Anthrax lateralis Say, A. lucifer F., Bombylius sp., Systoechus vugaris Lw., Systropus macer Lw., Toxophora amphitea Wk., T. virgata O. S.; *Conop*: Conops excisus Wd., Dalmannia vitiosa Cq., Physocephala sagittaria Say, Zodion nanellum Lw.; *Ephydr*: Notiphila bicolor Cr., *type*, N. carinata Lw., Ochthera exculpta Lw.; *Musc*: Chrysomyia macellaria F., Lucilia caesar L., L. sericata Mg., L. sylvarum Mg., Musca domestica L., Synthesiomyia brasiliana B. & B.; *Ortal*: Euxesta notata Wd., Tephronota humilis Lw., *Oscin*: Chlorops unicolor Lw., Siphonella cinerea Lw.; *Sapromyz*: Pachycerina verticalis Lw.; *Sarcophag*: Helicobia helicis Tn., Metoposarcophaga pachyprocta Parker, Ravinia floridensis Ald., R. quadrisetosa Cq., Sarcophaga assidua Wk., S. bullata Parker, S. incerta Wk., S. utilis Ald., Sarcophagula occidua F.; *Seps*: Sepsis violacea Mg.; *Stratiomy;* Nemotelus glaber Lw., Odontomyia cincta Oliv., O. trivittata Say; *Syrph*: Allograpta obliqua Say, Baccha clavata F., B. tarchetius Wk., Ceria signifera Lw., Eristalis albiceps Mc., E. dimidiatus Wd., E. transversus Wd., Helophilus divisus Lw., H. similis Mc., Mallota cimbiciformis Flln., Mesogramma boscii Mc., M. marginata Say, Microdon viridis Tn., *type*, Milesia virginiensis Drury, Orthoneura nitida Wd., Paragus tibialis Flln., Psilota buccata Mc., Spilomyia hamifera Lw., Syrphus americanus Wd., Tropidia albistylum Mc., Volucella fasciata Mc., V. sexpunctata Lw., V. vesiculosa F., Xylota pigra F.; *Taban*: Tabanus sparus Whitney; *Tachin*: Archytas lateralis Mc., Atrophopalpus angusticornis Tn., *type*, Atrophopoda singularis Tn., Chaetoglossa picticornis Tn., *type*, C. violae Tn., *type*, Cylindromyia nana Tn., Ennyomma globosa Tn., *type*, Gonia capitata De Geer, G. senilis Wl., Gymnoprosopa polita Tn., *type*, Hypostena floridensis Tn., *type*, H. vanderwulpi Tn., Masiphya brasiliana B. & B., Pachyophthalmus floridensis Tn., Phasioclista metallica Tn., Phasiopsis floridensis Tn., *type*, Phorocera edwardsii Wl., Plagiprospherysa parvipalpis Wulp, Polistomyia histrio Wk., Senotainia rubriventris Mc., S. trilineata Wulp, Siphoclytia robertsonii Tn., *type,* Siphona geniculata De Geer, Siphophyto floridensis Tn., *type,* Siphosturmia rostrata Cq., Spallanzania hesperidarum Wl., Sturmia distincta Wd., Trichopoda pennipes F., Xanthomelana atripennis Say; *Trypet*: Neaspilota vernoniae Lw., Urellia solaris Lw.

LEPIDOPTERA (53).

Danaidae: Danaus archippus F., D. berenice Cm.; *Hesperi*: Achalarus lycidas S. & A., Amblyscirtes vialis Ed., Ancyloxypha numitor F., Atalopedes cempestris Bs., Atrytonopsis loammi Whitney, Cocceius pylades Scudder, Epargyreus tityrus F., Goniurus proteus L., Hylephila phylaeus Drury, Lerodea eufala Ed., Megistias fusca G. & R., Pamphila attalus Ed., Paratrytone aaroni Skinner, Polites baracoa Lucas, P. brettus Bs., P. cernes B. & L., Prenes ocola Ed., Thanaos brizo B. & L., T. juvenalis F., T. martialis Scudder, T. terentius S. & B., Thorybes daunus Cm.; *Lycaen*: Atlides halesus Cm., Hemiargus hanno Stoll, Strymon cecrops F., S. melinus Hbn.; *Nymphal*: Dione vanillae L., Junonia coenia Hbn., Phyciodes tharos Drury, Vanessa atalanta L., V. virginiensis Drury; *Papilion*: Papilio cresphontes Cm., P, glaucus L., P. marcellus Cm., P. philenor L., P. polydamas L., P. polyxenes F., P. troilus L.; *Pier*: Catopsilia eubule L., Eurema delia Cm., E. euterpe Menetries, E. nicippe Cm., Zerene caesonia Stoll; *Rhiodin*: Calephelis virginiensis Gray; *Satyr*: Cissia sosybius F.; *Sesi*: Synanthedon rubristigma Kellicott, S. geliformis Wk.; *Arcti*: Lerina incarnata Bs., Utetheisa bella L.; *Noctu*: Psychomorpha epimenis Drury; *Syntom*: Scepsis fulvicollis Hbn.

COLEOPTERA (15).

Buprestidae: Acmaeodera tubulus F.; *Carab*: Lebia pumila De jean; *Cerambyc*: Typocerus zebratus F.; *Chrysomel*: Donacia piscatrix Lac.; *Cler*: Trichodes apivorus Germar; *Dermest*: Attagenus piceus Oliv., Orphilus glabratus F.; *Elater*: Cardophorus gagates Erichson; *Lampyr*: Chauliognathus marginatus F., Polemius limbatus Lec.; *Mordell*: Mordella melaena Germar; *Scarabae*: Euphoria sepulchralis F., Trichius (Trichiotinus) affinis Gory, T. delta F., T. piger F.

HEMIPTERA (8).

Lygaeidae: Melanocoryphus facetus Say; *Pentatom*: Euschistus crassus Dallas, E. servus Say; *Phymat*: Phymata erosa L. var. guerini Lp. & S.; *Pyrrhocer*: Arhaphe carolina H. Schaeffer, Largus longulus Stal; *Reduvi*: Zelus cervicalis Stal, Z. bilobus Say.

When a genus contains only one species, the specific name is omitted in the tables. Thus *Apis* = *Apis mellifera* ☿.

Insects were identified for me by J. M. Aldrich, W. H. Ashmead, Nathan Banks, D. W. Coquillett, J. C. Crawford, E. T. Cresson, R. A. Cushman, W. J. Fox, G. H. French, C. A. Frost, A. B. Gahan, C. A. Hart, Samuel Henshaw, L. O. Howard, C. W. Johnson, Charles Liebeck, J. R. Malloch, H. M. Parshley, R. R. Parker, Theo. Pergande, S. A. Rohwer, C. H. T. Townsend, P. R. Uhler, and S. W. Williston.

Considerable difficulty has been found in getting the insects identified. I have been compelled to meddle with the business of the systematists and describe some bees and Eumenidae, or go without names. This has put me in the class of the jack-of-all-trades, giving the impression that I was collecting and describing bees from anywhere and everywhere, and I am offered specimens in exchange for local ones.

Sometimes insects sent by me for identification have been retained and identified for the persons who retained them, and it is often an accident that I find out the names. A chalcid was identified for me as *Leucospis distinguendus* and afterwards described as *L. robertsoni.* A syrphid identified as *Microdon coarctatus* was afterwards described as *M. viridis.* The same specimen of *Notiphila* was identified for me by three different dipterologists as *Dichaeta brevicauda, Notiphila carinata* and *N. bicolor.* One of these defended this practice because the correct name had not been assigned. But that would not be followed by any one who distinguished what he knew from what he was guessing at.

The best way to get species identified is to describe them yourself. One who will give you no aid in determining them will go 1000 miles to suppress them as synonyms.

Some author will describe species as if they differed only in size and color and deposit the types in a distant museum. You are not expected to read his descriptions but must examine the types to see what he described. His descriptions are ignored for many years. The species are described under other names, which become associated with an extensive literature. Finally the types are examined and familiar names are upset. The only competent thing is for the systematists to clear up the old names at first.

My experience is that the best time to get species identified is when an author is working on the group, when he is competent to determine species or compare types. It is hard to strike authors at that time. I have had probable new species of Cerceridae lying in my collection while three authors, one after the other, were working on them. About the time you desire to send cercerids to one of these, he is working on may-flies or spiders, like a flitting schmetterling. I happened to strike Townsend when he was working on Tachinidae and got many of them identified, nine being types of new species.

Descriptions of bees in which the sexes are separated as distinct species are worthless for identification.

Nomenclature is synonymical, not binomial. No one has any authority to ignore priority*, but the historically correct name often has no relation to the literature.

ACANTHACEAE.

CALOPHANES OBLONGIFOLIA, Ma., R.—The stems rise 1 dm. or less, and bear three or four flowers open at a time. The corolla is 2 to 3 cm. long, expands 2 cm. The throat is 1 cm. long and 7 to 8 mm. wide, narrowing rather strongly to the tube which is 1 cm. long. The corolla is blue, but the throat below is marked with purple. The flowers are nototribe and proterandrous. The throat is so wide that a bee which presses its thorax against the anthers readily effects pollination. Butterflies can suck the nectar without much probability of effecting pollination. Mr. 15-Ap. 29, 17 species, 100 individuals observed, Ap. 4-9.

LONG-TONGUED BEES (4:14)—*Anthophor.*: Centris ♂ 1; *Bomb.*: Bombus americanorum ♀ 1; *Eucer.* (♂): Melissodes sp. 1, M. variabilis 11. SHORT-TONGUED BEES (3:5, ♀)—*Halict.*: Agapostemon 1, Odontalictus 1, Oxystoglossa austrina 3, n. OTHER HYMENOPTERA (1:1)—

*There are people who ignore history just as there are people who legislate to make more than one-half of one per cent of alcohol intoxicating instead of being appropriated as food, to limit a patient's needs to one pint in 10 days, and to propagate the fake biology which ignores evolution.

Sphec.: Sphex procera 1. Diptera (1:12)—*Bombyli.*: Systoechus 12. Lepidoptera (8:68, n.)—*Hesperi.*: Lerodea 1, Pamphila 4, Polites baracoa 2, P. brettus 47; *Nymphal.*: *Junonia* 1; *Papilion.*: Papilio philenor 3, P. polydamas 3; *Pier.*: Eurema nicippe 7.

Ruellia Humilis, Ma., R.—Mr. 12-Ap. 28, 3 visitors observed, Mr. 14-26.

Lepidoptera (3)—*Hesperi.*: Pamphila; *Papilion.*: Papilio philenor, P. polydamas.

ANONACEAE.

Asimina Obovata, Mi., W.—Mr. 15-Ap. 26, 4 species and 9 individuals observed, Ap. 8-14.

Coleoptera (3:8)—*Cerambyc.*: Typocerus 1; *Scarabae.*: Trichius affinis, 1, T. piger 6. Hemiptera (1:1)—*Pentatom.*: Euschistus crassus 1.

APOCYNACEAE.

Amsonia Ciliata, Ma., R. — The stem is terminated by a conspicuous panicle of pale bluish flowers. The corolla is tubular, with a border of 5 lobes. It measures 14 mm. across. The tube is slender and measures 7 mm. in length. In the upper part, occupied by the anthers and stigma, it is broader. The throat is densely bearded, shielding the pollen from intruders.

The anthers surpass the stigma, so that self-pollination is not likely. The pollen is discharged in a mass. The stigma is lateral and appears quite viscid. When an insect inserts its tongue the viscid matter may readily adhere to it and catch the pollen.

Long-tongued bees commonly show a mass of pollen on their maxillary laminae, but butterflies never do. It is doubtful whether butterflies ever carry the pollen. Mr. 8-

Ap. 26, visitors observed Mr. 18-Ap. 25. The following 5 species and 49 individuals carried pollen:

LONG-TONGUED BEES (5:49)—*Anthophor.*: Centris ♂ ♀, 2; *Bomb.*: Bombus americanorum ♀, 6; *Eucer.* (♂ ♀): Florilegus 7, Melissodes sp. 18, M. variabilis 16.

The following 28 species and 112 individuals carried no pollen:

LONG-TONGUED BEES (7:19)—*Anthophor.*: *Centris* 3; *Bomb.*: Bombus americanorum 4; *Eucer.*: Florilegus 5, Melissodes sp. 1, M. variabilis 3; *Megachil.* (♂): Lithurgus 1, Megachile generosa 2. OTHER HYMENOPTERA (3:5)—*Sphec.*: Isodontia cinerea 1; *Scoli.*: Campsomeris quadrinotata 1, Discolia 3. DIPTERA (2:12)—*Bombyli.*: Bombylius 1, Systoechus 11. LEPIDOPTERA (15:75)—*Dana.*: Danaus berenice 1; *Hesperi.*: Hylephila 3, Megistias 1, Pamphila 6, Polites baracoa 41, P. brettus 1, P. cernes 9, Thorybes 3; *Nymphal.*: Dione 1, Junonia 1; *Papilion.*: Papilio cresphontes 1, P. marcellus 1, P. philenor 4, P. troilus 1; *Pier.*: Catopsilia 1. COLEOPTERA (1:1) —*Lampyr.*: Chauliognathus 1.

ASCLEPIADACEAE.

ASCLEPIAS AMPLEXICAULIS, Mas, R.—Mr. 8-Ap. 26, 33 species and 237 individuals observed, Mr. 19-Ap. 23.

The following 17 species and 66 individuals carried pollinia; h = on tarsal hairs, lp = on labial palps:

LONG-TONGUED BEES (1:3)—*Megachil.*: Megachile generosa ♂ ♀, lp, 3. SHORT-TONGUED BEES (2:2 ♀)—*Halict.*: Augochlora sumtuosa h, 1, Oxystoglossa austrina lp, 1. OTHER HYMENOPTERA (5:15)—*Bembic.*: Bembix h, 2, Microbembex h, 1; *Eumen.*: Leionotus foraminatus, on claws, 1; *Sphec.*: Priononyx h, 10; *Scoli.*: Discolia h, 1. DIPTERA (1:1)—*Bombyli.*: Systoechus, on pulvilli 1. LEPI-

DOPTERA (8:45, h)—*Hesperi.*: Achalarus 1, Cocceius 1, Pamphila 11, Polites baracoa 23, P. brettus 2, P. cernes 2, Thorybes 4; *Nymphal.*: Junonia 1.

The following 172 individuals, belonging to 27 species, carried no pollinia:

LONG-TONGUED BEES (2:32)—*Megachil.*: Coelioxys 8-dentata ♂, 1; Megachile generosa 31. SHORT-TONGUED BEES (3:8 ♀)—*Halict.*: Chloralictus floridanus 2, C. nymphalis 1, Oxystoglossa austrina 5. OTHER HYMENOPTERA (7:26)—*Bembic.*: Bembix 3, Microbembex 2; *Eumen.*: Leionotus arvensis 2; *Larr.*: Tachytes pepticus var. floridanus 2, *type; Sphec.*: Priononyx 15; *Scoli.*: Campsomeris plumipes 1, C. quadrinotata 1. DIPTERA (2:3)—*Conop.*: Zodion 2; *Taban.*: Tabanus 1, LEPIDOPTERA (11:99)—*Dana.*: Danaus archippus 1, D. berenice 3; *Hesperi.*: Cocceius 2, Pamphila 9, Polites baracoa 11, P. cernes 1, Thorybes 1; *Nymphal.*: Junonia 2; *Papilion.*: Papilio marcellus 1, P. philenor 1; *Pier.*: Zerene 1. COLEOPTERA (1:2)—*Lampyr.*: Chauliognathus 2. HEMIPTERA (1:2)—*Reduvi.*: Zelus cervicalis 2.

The Lepidoptera show the highest percentages of species and individuals both with and without pollinia. Of the species, 42.1% but of the individuals 31.2% show pollinia. Of Other Hymenoptera individuals, 36.5% show pollinia. Only 11.1% of bee individuals show them. The most common bee, *Megachile generosa*, showed 34 individuals, of which only 3 carried pollinia, and then only on the labial palps.

ASCLEPIAS VERTICILLATA, Pol, W.—Mr. 4-17, one visitor observed at Orlando, Mr. 4.

OTHER HYMENOPTERA (1)—*Tenthredin.*: Pseudosiobla, pollinia on legs, tongue and face.

AURANTIACEAE.

CITRUS AURANTIUM, Ma, W.—Visitors observed Mr. 31.

LONG-TONGUED BEES (3)—*Bomb.*: Bombus americanorum ♀, sc, ab; B. impatiens ♀ ☿; *Xylocop.*: Xylocopa virginica ♀. OTHER HYMENOPTERA (3)—*Larr.*: Tachytes aurulentus; *Scoli.*: Campsomeris quadrinotata fq; *Vesp.*: Vespula. LEPIDOPTERA (3)—*Nymphal.*: Junonia; *Papilion.*: Papilio philenor; *Pier.*: Catopsilia.

CACTACEAE.

OPUNTIA AUSTRINA, Ma., Y. Mr. 30-Ap. 29, 15 species, 51 individuals observed, Ap. 7-25.

LONG-TONGUED BEES (7:31)—*Bomb.*: Bombias scutellaris ♀, 1; *Eucer.*: Melissodes variabilis ♂ ♀, sc, 13; *Megachil.*: Ashmeadiella ♀, c, 1; Lithurgus ♂ ♀, sc, 13; megachile generosa ♀, 1, M. lanuginosa ♂, 1, M. mendica ♂, 1. SHORT-TONGUED BEES (2:4, ♀, c)—*Halict.*: Agapostemon 3, Chloralictus numphalis 1. LEPIDOPTERA (4:5)—*Hesperi.*: Pamphila 1, Polites brettus 2; *Papilion.*: Papilio philenor 1; *Pier.*: Eurema nicippe 1. COLEOPTERA (2:11, f)—*Mordell.*: Mordella 1; *Scarabae.*: Trichius piger 10, in cop.

CAPRIFOLIACEAE.

LONICERA SEMPERVIRENS, Ma. (0) R.

BIRDS (1)—*Trochil.*: Trochilus ab.

LEPIDOPTERA (1)—*Papilion.*: Papilio cresphontes.

CISTACEAE.

HELIANTHEMUM CAROLINIANUM, Ma., Y. F. 2-Ap. 29. The stems rise a few inches and bear solitary, yellow flowers an inch or more in width. The petals are obovate and are expanded horizontally. The numerous stamens are also horizontal, their dehiscent anthers facing upwards. In this position there is no chance of the pollen touching the stigma. The large stigma is sessile. If a large bee loaded with pollen lands upon the flower it must dust the stigma before touching the anthers. Cross-pollination in this case is between different plants. If the insect does not bear pollen, it may readily effect self-pollination. The flower is visited exclusively for pollen, the petals, as in most pollen-flowers, soon falling. Females of small Halictidae, *Chloralictus, Evylaeus* and *Oxystoglossa,* were observed collecting pollen.

COMPOSITAE.

Berlandiera Subacaulis, Mas, Y.—The heads are single on the scapes and measure about one inch across. There are 8 to 10 broad, yellow ray-flowers which are pistillate. The lobes of the style are long, nearly erect, with stigmatic edges. The disc florets have nectar-bearing tubes 4 mm. deep. They are staminate, the pollen being carried out on a long style brush, as in *Silphium.* Ja. 10-Ap. 29, 14 visitors observed F. 27-Ap. 4.

Long-tongued Bees (2)—*Megachil.*: Coelioxys sayi ♀, Megachile lanuginosa ♂. Short-tongued Bees (5, ♀)—*Halict.*: Augochlora sumptuosa, Chloralictus floridanus sc, Evylaeus nelumbonis, E. pectoralis, Odontalictus sc. Diptera (2)—*Bombyli.*: Anthrax lucifer; *Tachin.*: Chaetoglossa picticornis. Lepidoptera (5)— *Hesperi.*: Polites baracoa, Thorybes; *Nymphal.*: Phyciodes; *Pier.*: Eurema nicippe; *Rhiodin.*: Calephelis.

On ten days, Mr. 7-21, the following 300 individuals were taken on flowers:

Long-tongued Bees (8)—Ap. 1, *Epeol.* 3; *Megachil.* 4. Short-tongued Bees (216)—*Halict.* 216. Diptera (9)—

Bombyli. 5, *Syrph.* 4. LEPIDOPTERA (67)—*Arcti.* 1, *Hesperi.* 43, *Nymphal.* 12, *Papilion.* 7, *Pier.* 4.

Odontalictus capitosus ♀, belonging to Halictidae, 8.3% of the families represented, showed 65.3% of the individuals.

CARDUUS SP., Mas, R.—One visitor observed at Orlando, Mr. 21.

LONG-TONGUED BEES (1)—*Emphor.*: Melitoma ♂ ♀.

LYGODESMIA APHYLLA, Mas, R.—Mr. 21-Ap. 29, 5 species and 15 individuals observed, Ap. 6-12.

LONG-TONGUED BEES (1:1)—*Megachil.*: Lithurgus ♂, 1. SHORT-TONGUED BEES (1:1, ♀, c, n)—*Halict.*: Chloralictus floridanus. LEPIDOPTERA (2:12)—*Hesperi.*: Pamphila 6, Polites brettus 6. COLEOPTERA (1:1, f, n)—*Scarabae.*: Trichius affinis 1.

ERICACEAE.

BATODENDRON ARBOREUM, Ma, W.—The trees rise several metres and are fairly white with flowers, which are arranged in small racemes. The corolla is 4 mm. wide at the thoat, so that the bodies of small insects are admitted. The lobes are slightly reflexed, enabling bees to cling to them more readily. The corolla is 7 mm. long, its tube 5 mm. The filaments have a pair of awns, which when struck, cause a downpour of dry pollen. Nectar is secreted by an epigynous disc. To reach it a tongue must be thrust between the filaments. The latter are hairy, which helps to protect the nectar and to cause a pollen discharge.

The flowers are homogamous. Cross-pollination is secured by the stigma being far in advance of the anthers.

In their first visits bees may effect self-pollination. In the absence of insects self-pollination may occur by the pollen falling upon the slightly projecting rim of the stigma. F. 22-Ap. 24, 26 species and 68 individuals observed, Mr. 16, 23, Ap. 5.

Long-tongued Bees (5:25)—*Anthophor.*: Emphoropsis ♀, sc, 7; *Bomb.*: Bombias separatus ☿, sc, 1, Bombus impatiens ♀ ☿, sc, 9; *Xylocop.*: Xylocopa micans ♀, 1, X. virginica ♂ ♀, 7. Short-tongued Bees (3:7, ♀)—*Halict.* (sc): Agapostemon 5, Evylaeus pectoralis 1; *Prosopid.*: Prosopis flammipes 1, *type.* Other Hymenoptera (8:17)—*Eumen.*: Leionotus apopkensis 1, L. megaera 2, Monobia 5; *Scoli.*: Campsomeris plumipes 2, C. quadrinotata 4; *Vesp.*: Polistes americanus 1, P. pallipes 1, P. rubiginosus 1. Diptera (2:3)—*Musc.*: Chrysomyia 1; *Syrph.*: Milesia 2. Lepidoptera (8:16)—*Hesperi.*: Cocceius 1, Epargyreus 1, Goniurus 1; Thanaos juvenalis 1; *Papilion.*: Papilio cresphontes 2, P. marcellus 3, P. philenor 6, P. troilus 1.

Gaylussacia Hirtella, Ma., W.—F. 17, 18, 9 species and 28 individuals were observed at Orlando.

Long-tongued Bees (1:1 ♀)—*Bomb.*: Bombias separatus 1. Short-tongued Bees (1:5 ♀)—*Halict.*: Augochlora fulgida 5. Other Hymenoptera (7:22)—*Eumen.* (at holes, n): Eumenes smithii 1, Leionotus histrio 3, Odynerus 7, *perforating; Scoli.*: Campsomeris plumipes 1, C. quadrinotata 5; *Vesp.* (at holes, n): Polistes americanus 4, P. pallipes 1.

Pieris Nitida, Ma., R. — The stems rise one or two metres and the ends of the branches are crowded with pendulous flowers. The corolla is cylindraceous with a gibbous base. It is from 7 to 9 mm. long and is contracted in the throat to 1 or 2 mm. The stamens and stigma are included. The filaments are crumpled and at the apex are two-awned, so that an entering tongue is certain to touch them and shake out the loose pollen. Blooms February 2-April 26, 1 visitor observed, February 19.

LEPIDOPTERA (1)—*Hesperi.*: Thanaos juvenalis.

VICCINIUM NITIDUM, Ma., W.—The corolla is white, often with a reddish tinge, urceolate, 5 mm. long. The mouth is so constructed that all except the smaller insects are excluded, and for ordinary ones a tongue 5 mm. long is needed to obtain the nectar. The bee touches the exserted stigma before the included anthers. The anthers have scarious tips with terminal pores through which the light pollen is sifted down upon the visitor. Nectar is secreted by the thickened epigynous disc. Ja. 24-Ap. 23, 18 visitors observed, F. 16-M. 7.

LONG-TONGUED BEES (2)—*Anthophor.*: Emphoropsis ♂ ♀, fq; *Megachil.*: Megachile lonuginosa ♂. SHORT-TONGUED BEES (1, ♀)—*Halict.*: Chloralictus longiceps. OTHER HYMENOPTERA (3)—*Eumen.*: Odynerus, *perforating,* n; *Scoli.*: Campsomeris plumipes fq, C. quadrinotata fq. LEPIDOPTERA (12)—*Hesperi.*: Cocceius, Polites baracoa, Thanaos juvenalis, T. martialis, T. terentius, Thorybes; *Nymphal.*: Vanessa virginiensis; *Papilion.*: Papilio marcellus, P. philenor, P. troilus; *Pieri.*: Eurema nicippe, Zerene.

XOLISMA FERRUGINEA, Ma., W.—The ends of the branches are crowded with white flowers.

The corolla is nearly globular, 3 or 4 mm. long by 4 mm. wide at the base and 2 mm. wide at the 5-toothed throat. The 10 stamens and the style are included. The anthers have terminal pores and hold their tips against the style. A bee's tongue disturbs the anthers and the pollen is sifted out. The pollen does not fall upon the stigma, though its edge may receive some.

The pendulous position favors bees, which easily hang upon the flowers, but butterflies also effect cross-pollination. The mouth of the corolla is so narrow that only bees with tongues about 4 mm. can drain the nectar. F. 2-Ap. 24, 6 visitors observed, F. 2-Ap. 5.

Long-tongued Bees (3)—*Anthophor.*: Emphoropsis ♂ ♀, sc, fq; *Ap.*: Apis; *Bomb.*: Bombus impatiens ♀ ☿. Other Hymenoptera (1)—*Scoli.*: Campsomeris quadrinotata. Lepidoptera (2)—*Hesperi*: Thanaos martialis; *Papilion.*: Papilio marcellus.

ERIOCAULONACEAE.

Eriocaulon sp., Mis, W.—F. 7-Ap. 26, 9 species and 29 individuals observed, F. 29.

Long-tongued Bees (1)—*Ceratin.*: Ceratina ♂, 1. Short-tongued Bees (4:23)—*Halict.* (♀): Chloralictus ashmeadii 12, C. nymphalis 5, Evylaeus nelumbonis 1; *Prosopid.*: Prosopis schwartzii ♂ ♀, 5. Diptera (3:4)—*Syrph.*: Masogramma boscii 1, M. marginata 2, Tropidia 1. Lepidoptera (1:1)—*Nymphal.*: Phyciodes 1.

EUPHORBIACEAE.

Cnidoscolus Stimulosus, Ma., W.—F. 8-Ap. 29, 2 visitors observed, Mr. 19, Ap. 4.

Diptera (1)—*Bombyli.*: Anthrax lucifer. Lepidoptera (1)—*Hesperi.*: Thorbyes. Individuals observed Mr. 16, 17, 19, 21, were 15 Hesperiidae.

HYPERICACEAE.

ASCYRUM TETRAPETALUM, Ma., Y.—The four yellow petals are horizontal, the flower measuring an inch across. The numerous stamens dehisce in succession. Since the stamens are turned more or less outward, the anthers do not touch the stigmas. An insect coming with pollen may readily effect pollination before touching the anthers. Otherwise, it may effect self-pollination. The flower seems to be visited only for pollen. F. 2-Ap. 26, 4 visitors observed, F. 18-Mr. 23.

LONG-TONGUED BEES (1)—*Megachil.*: Megachile lanuginosa ♀, c, and n, cutting petals. SHORT-TONGUED BEES (1)—*Halict.*: Chloralictus nymphalis ♀, c. DIPTERA (1)—*Syrph.*: Mesogramma marginata f. COLEOPTERA (1)—*Buprest.*: Acmaeodera f.

LEGUMINOSAE.

CROTALARIA ROTUNDIFOLIA, Ma., Y. — The flowers are separated on the racemes, so that only a few on different stems are open at the same time. The insect must land on each flower separately, and the flowers must receive pollen from separate stems and commonly from separate plants.

The flowers are yellow. The banner is nearly orbicular, measuring 8 mm. across and is erect or reflexed. Its claw projects forward, and with the calyx serves to hide the nectar so that a tongue 3 mm. long is needed to drain it. At base the banner has cushions which serve the bee as a head-rest when forcing down the keel. The wings are short, of an orange red color, forming a path-finder, and are folded close around the keel, so that the latter dispenses entirely with its color. The base of the wings lie upon the base of the keel and their tips so closely envelope it that all are forced down together and, when released, return to their former position. The keel is saccate at base, turns abruptly upward and ends in a slender beak.

The stamens are monadelphous, a round opening in the tube at base above allowing access to the nectar. When the flower opens five oblong anthers have discharged their pollen and five rounded anthers are still indehiscent. In the bud the long anthers surpass the others. The five stamens with long anthers rise to the tip of the keel, shed their pollen, and then withdraw. The five stamens with round anthers then lengthen, their indehiscent anthers serving to push the pollen up into the apex of the keel. Then they shed their own pollen where it will be easily carried out by the style-brush.

The style bends abruptly upward, and has a fringe of hairs above and a circle of hairs about the tip. When the keel is depressed, the style pushes out a ribbon of pollen. If the keel be further depressed, the style itself appears carrying out more pollen upon its brush. Ja. 21-Ap. 29, 13 species, 90 individuals observed, F. 20-Ap. 20.

Long-tongued Bees (9:71)—*Anthophor.*: Centris ♀, 1; *Megachil.*: Ashmeadiella floridana ♂ ♀, sc, 13, *type*, Diceratosmia ♂, 1, Megachile generosa ♂ ♀, 9, M. lanuginosa ♂ ♀, sc, 20, M. mendica ♂, 7, Sarogaster ♂ ♀, sc, 9; *Stelid.* (♂ ♀, sc): Dianthidium notatum 4, D. perplexum 7. Diptera (1:1, n)—*Bombyli.*: Systoechus 1. Lepidoptera (3:18, n)—*Hesperi.*: Polites baracoa 16, Thanos brizo 1, Thorybes 1.

Erythrina Herbacea, Ma. (0), R.—Several stems rise 2 to 4 feet and bear scarlet flowers in racemes 1 to 2 feet long. The flowers are about 2 inches long. The calyx tube is 10 mm. with short lobes. The wings and keel are almost entirely included in the calyx tube, serving merely as a protection to the stamens on the lower side. The banner is folded longitudinally. At base it enfolds the stamens, wings and keel and is itself enfolded by the calyx tube. Access to the nectar is on each side of the free filament. The stamens are of unequal length, so that the anthers form a pollen surface 12 mm. in length. They are enclosed in the infolded banner, but their tips are slightly exposed below. Visitors must have a proboscis 1½ inches or more to reach the nectar conveniently. The stigma stands among the anthers and may easily receive their pollen, but the way neglected flowers fall seems to show that self-fertilization does not occur. It is evidently adapted to humming birds, and dusts their throats with pollen. F. 26-Ap. 29.

BIRDS (1)—*Trochil.*: Trochilus ab.

LUPINUS DIFFUSUS, Ma., R.—Often the plants grow in clusters a few feet across, which increases the conspicuousness of the flowers. The racemes are erect and densely flowered.

The flower is 15 mm. long. The banner has its blade entirely exposed, since it has mainly an attractive function. At base it runs forward and is creased so as to give a head-rest to bees depressing the keel. It is blue with a longitudinal white spot, which forms a path-finder. It is nearly orbicular, 12 mm. across.

The wings form a colored envelope of the keel. They are coalescent at tip and move with the keel so as to keep it concealed.

The keel is falcate, without color, and is bent abruptly upward, ending in a sharp beak, as in *Crotalaria*. The keel petals are coalescent above and below, leaving a small opening at the tip.

The absence of an opening in the stamen tube shows that nectar is wanting, and that the flowers are adapted to female nest-making bees, but they are visited by other insects. In the bud the oblong anthers dehisce, filling the tip of the keel with pollen. When the flower opens, the round anthers are still closed. They no doubt aid in forcing the pollen of the long anthers into the tip of the keel and then dehisce.

The tip of the style is provided with a brush of hairs, which, when the keel is depressed, forces the pollen out of the tip of the keel. A long ribbon of pollen first appears and then the tip of the style. The style returns to its former position when the keel is released, and then, when the keel is forced down, again sweeps out the pollen. F. 7-Ap. 26, 29 species, 93 individuals observed, Mr. 5-Ap. 5.

LONG-TONGUED BEES (10:35)—*Anthophor.*: Emphoropsis ♀, sc, 1; *Ap.*: Apis sc, 2; *Bomb.*: Bombus americanorum ♀, 1; *Megachil.*: Coelioxys octodentata ♂, 1, C. sayi ♂ ♀, 5, Megachile floridana ♂, 1, *type,* M. generosa ♂ ♀, 7, M. lanuginosa ♂ ♀, sc., 7, M. mendica ♂ ♀, sc., 8, Sarogaster ♂, 2. SHORT-TONGUED BEES (2:9)—*Halict.*: Augochlora sumptuosa ♀, c., 2, Chloralictus floridanus ♀, fsp., 7, *type.* LEPIDOPTERA (17:49, n.)—*Hesperi.*: Achalarus 1, Cocceius 2, Hylephila 1, Lerodea 6, Megistias 1, Pamphila 3, Polites baracoa 2, P. brettus 7, Thanaos juvenalis 1, T. martialis 1, Thorybes 13; *Lycaen.*: Strymon melinus 1; *Nymphal.*: Junonia 2, Vanessa virginiensis 1; *Papilion.*: Papilio philenor 5, P. troilus 1; *Pier.*: Eurema nicippe 1.

TIUM INTONSUM, Ma., Y.—The stems are prostrate, the short, dense-flowered racemes only turning up from the ground. The flower is pale yellow and measures 11 mm. The calyx tube measures 3 or 4 mm.

The banner runs forward for 5 mm., its claw, as well as the claws of the other petals, being held by the calyx tube. To reach the nectar a tongue 4 or 5 mm. long is needed. The banner then bends upward, being concave in front and strongly reflexed on the sides. As it appears in front, it measures 7 mm. high and 4 mm. wide. The folds render it quite rigid, so that it resists upward pressure.

The wings are free, lying close to the keel, their tips being bent to the right. This requires the bee to land on the right side and, as in *T. obcordatum,* pollen contact is limited mainly to the left cheek. This slight disposition of the wings makes the flower *pleurotribe.* A process in each wing fits in a pit in the keel, requiring the parts to move together. On the base of each wing is a hook-like process which clasps the stamen tube and prevents the wings and keel from being thrust aside.

The keel petals are united. When the keel is depressed, all of the stamens are exposed. When freed, the keel again covers them.

The stigma receives pollen from the bee before the anthers touch it. Self-pollination is hardly probable. Access to the nectar is on each side of the free stamen. F. 19-Ap. 16, 2 visitors observed, F. 25.

Lepidoptera (2, n.)—*Hesperi.*: Amblyscirtes, Polites baracoa.

Tium Obcordatum, Ma., R.—It grows flat on the ground, and bears short racemes of pale-bluish flowers, the tip of the keel being of a darker blue. The flower is 10 mm. long, the banner 5 mm. wide. The banner runs forward for 6 mm., when it turns obliquely upward. At base the banner clasps the other petals and is itself clasped by the calyx, so that it resists the entrance of small insects and limits the visitors to those having a tongue 5 or 6 mm. long. On the base of the banner is a large pale spot crossed by purple lines which run inwards, forming pathfinders. The keel petals are united. A process in each wing fits in a depression in the keel, so that keel and wings are depressed together.

Both wings turn to the right, which requires the bee to land on the right. The bees taken on the flowers had pollen on the left cheek, so that the flower is *pleurotribe*. When the keel is forced down, the stigma and after it the dehiscent anthers strike the bee, the stigma thus receiving pollen from other flowers. Self-pollination can hardly occur if the flowers remains undisturbed. F. 16-Ap. 23, 5 species and 19 individuals observed, F.17-29.

Long-tongued Bees (2:13, ♂)—*Megachil.*: Diceratosmia 4, Megachile lanuginosa 9. Lepidoptera (3:6, n.)—*Hesperi.*: Amblyscirtes 3, Polites baracoa 1, Thorybes 2.

Vicia Acutifolia, Ma., W.—The flower is 9 mm. long, the abcordate banner 6 mm. wide. The banner is pale bluish, marked in the middle with purplish streaks, which, with the purple tip of the keel, form pathfinders. Elsewhere the flower is white.

The banner has a broad base, enclosing the other petals. It runs forward for 6 mm., thus limiting access to the nectar. The wings lie alongside the keel, hiding it from view, their tips far surpassing it. They are united with the keel and move with it. The keel is short (6 mm.), its petals united. Access to the nectar is on each side of the free filament. When the keel is depressed the anthers are exposed, but most of the pollen is deposited on the style-brush. The style turns up and is bearded near the tip. Mr. 9-Ap. 26, 4 visitors observed, Mr. 11-Ap. 3.

Long-tongued Bees (1)—*Anthophor.*: Emphoropsis ♀. Lepidoptera (3, n.)—*Hesperi.*: Polites baracoa; *Nymphal.*: Phyciodes; *Pier.*: Eurema euterpe.

LENTIBULARIACEAE.

Pinguicula Elatior, Ma., R.—Mr. 16-Ap. 3, 2 visitors observed at Orlando, Mr. 16.

Long-tongued Bees (2, ♀, c., reversing)—*Megachil.;* Megachile lanuginosa, M. mendica.

Pinguicula Lutea, Ma., Y.—F. 19-Mr. 24, 2 visitors observed, F. 19.

Short-tongued Bees (2, ♀)—*Halict.*: Agapostemon, Odontalictus.

Pinguicula Pumila, Ma., W.—Each plant commonly bears a single scape. Only one flower is open at a time, so that cross-pollination between distinct plants is usual.

The corolla varies from white to bluish-purple. The white form has the tube yellow within, 4 or 5 reddish streaks on the upper wall forming pathfinders. The purplish form has the tube darker purple within and the same pathfinders. The corolla is 10 to 16 mm. long and 7 to 10 mm. wide. The tube measures from 5 to 7 mm., the spur 4 to 5 m., so that a tongue 9 to 12 mm. long is needed to drain the spur. The tube of the corolla is only 2 or 3 mm. wide.

The stigma is just above the mouth of the spur, where the proboscis of the visitor is certain to strike it. The lower wall of the tube is folded inward longitudinally and is covered with glandular hairs, requiring the insect's tongue to pass nearer the upper wall and so in contact with the stigma. The stigma is a valvular flap, turned backward over the two anthers. When a butterfly withdraws its tongue the stigma is turned forward and the tongue comes in contact with the anthers.

The flower is nearly erect and its border almost horizontal. It remains open all day. It may also be visited by night-flying lepidoptera. J. 24-Ap. 5, 10 visitors observed, F. 18-23.

Short-tongued Bees (1)—*Halict.*: Evylaeus pectoralis ♀. Lepidoptera (9)—*Hesperi.*: Amblyscirtes, Lerodea, Megistias, Polites baracoa, Thanaos juvenalis; *Nymphal.*: Phyciodes; *Papilion.*: Papilio philenor; *Pier.*: Eurema nicippe, Zerene.

Utriculata Inflata, Ma., Y.—The scape is supported on the water by a whorl of leaves and bears several flowers. The corolla is 18 mm. long and 9 to 12 mm. wide. The upper lip is 11 mm. long and 9 mm. wide. In its basal concavity is situated the stigma and two stamens. The lower lip has a palate which rises 5 mm. above its base and shuts against the upper lip, concealing stamens and pistil and closing the spur. The flower is yellow, some reddish streaks on the palate forming path-finders. Below, the lower lip is three-lobed and lies in contact with the spur.

The spur is saccate, notched at the tip, has a large mouth and is 8 mm. long. The valve-like stigma lies upon and conceals the anthers. Later it rises so as to expose them. Nectar is secreted by the spur. The flowers remain open a few days. Cross-pollination results from insect visits and self-pollination can hardly occur. Only one or two flowers on the scape are open at a time. The flower is evidently adapted to bees which know how to depress the palate. Butterflies might steal nectar without transferring pollen.

Plants were found rising from the bottom in 9½ feet of water in Tsala Apopka Lake. The flowers sometimes open while they are still two or three feet below the surface. After the flowers reach the surface the stems separate from the ground but remain anchored by surrounding plants. Ja. 7-Ap. 20, 5 visitors observed, F. 19.

Short-tongued Bees (3, ♀)—*Halict.*: Chloralictus reticulatus, Evylaeus nelumbonis; *Prosopid.*: Prosopis schwartzii. Lepidoptera (2, n.)—*Hesperi.*: Thorybes; *Pier.*: Catopsilia.

Utricularia Subulata, Mi., Y.—The slender scape rises 3 or 4 inches and bears two or three flowers, only one of which is open at a time; so that pollination is between distinct plants. Sometimes the plants form thin patches quite attractive to insects.

The flower is 6 to 11 mm. long, the lower lip 5 to 8 mm. wide. In a general way it resembles *U. inflata.* The flower is entirely yellow. The spur measures 5 to 7 mm. The lower lip forms a convenient landing place, and the weight of the insect opens the spur.

When insect visits fail, self-pollination probably occurs from the stigma curling up so as to touch the pollen. Ja. 11-Ap. 4, 2 visits observed, F. 28, Mr. 2.

Lepidoptera (2, n.) — *Hesperi.*: Polites baracoa, Thanaos terentius.

MALVACEAE.

Sida Rhombifolia, Mi., W.—Ja. 11-Ap. 28, 1 visitor observed, Mr. 22.

Lepidoptera (1)—*Hesperi.*: Polites baracoa.

NYMPHAEACEAE.

Castalia Reniformis, Mi., W.—F. 17-Ap. 20, 3 visitors observed at Orlando, Mr. 18-Ap. 2.

Short-tongued Bees (2)—*Halict.*: Agapostemon ♀, c.; *Prosopid.*: Prosopis schwartzii ♂ ♀, f. Diptera (1)—*Ephydr.*: Notiphila bicolor fq., *type.*

Little plants, growing in shallow water, with peduncles 9-19 dm. long, and petioles 18-25 dm., probably belong to a different species. See *Nymphaea odorata* (3,125). One visitor observed at Orlando, F. 24.

Short-tongued Bees (1)—*Halict.*: Evylaeus nelumbonis ♀, c.

Nymphaea Advena, Mi., Y. (3,123)—Ja. 11-Ap. 26, 6 visitors observed at Orlando, F. 18-Ap. 11.

Short-tongued Bees (3)—*Halict.* (♀, sc.): Agapostemon, Evylaeus nelumbonis ab.; *Prosopid.*: Prosopis schwartzii ♂. Diptera (2)—*Ephydr.*: Notiphila carinata; *Syrph.*: Helophilus divisus. Coleoptera (1)—*Chrysomel.*: Donacia f., gn., in cop., ab.

OLEACEAE.

Osmanthus Americana, Mis., W.—The ends of the branches are full of flowers. The corolla with its 4 broad, revolute lobes measures 5 mm. across. The tube is 2 or 3 mm. long and 2 mm. wide in the throat, so that the nectar is quite accessible. F. 22-Mr. 31, 5 visitors observed, F. 22, 26.

Long-tongued Bees (2)—*Anthophor.*: Emphoropsis ♀; *Xylocop.*: Xylocopa virginica ♂. Other Hymenoptera (1)—*Vesp.*: Polistes rubiginosus. Lepidoptera (2)—*Lycaen.*: Strymon cecrops; *Papilion.*: Papilio marcellus.

ORCHIDACEAE.

IBIDIUM GRACILE, Ma., W., Spiranthes gracilis in 7, 52—F. 17-Mr. 16, 1 visitor observed at Orlando, F. 17.

LONG-TONGUED BEES (1)—*Megachil.*: Megachile lanuginosa ♂, pollinia on maxillary laminae.

LIMODORUM SP., Ma., R., Calopogon pulchellus in 1—F. 21-Mr. 16, 9 visitors observed at Orlando.

LONG-TONGUED BEES (2, ♀)—*Bomb.*: Bombias separatus n.; *Megachil.*: Megachile lanuginosa with pollinia. SHORT-TONGUED BEES (6, ♀)—*Halict.*: Augochlora fulgida with pollinia, A. sumptuosa with pollinia, Chloralictus ashmeadii n., Evylaeus nelumbonis n., Odontalictus n., Oxystoglossa sp., n. OTHER HYMENOPTERA (1)—*Eumen.*: Leionotus oculeus n., *type*.

POLYGALACEAE.

POLYGALA NANA, Ma., Y.—The flowers grow in close spikes. The early ones are sessile and their flowers appear to be habitually self-fertilized. The later spikes are borne on stems two or three inches high. The flowers are pale yellow, the tip of the keel more orange-yellow.

The keel bears a crest of 8 slender lobes. Pollen is deposited on a terminal tuft on the style. The stigma is lateral. Nothing seems to prevent pollen from the stamens being carried down to the stigma, though insects will no doubt effect cross-pollination. A proboscis 4 mm. long can easily exhaust the nectar. Ja. 26-Ap. 24, 1 visitor observed, Mr. 2.

LONG-TONGUED BEES (1)—*Megachil.*: Megachile lanuginosa ♂.

Polygala Polygama, Ma., R.—Mr. 22-Ap. 29, 3 visitors observed, Ap. 20.

Long-tongued Bees (1)—*Stelid.*: Dianthidium perplexum ♀.

Short-tongued Bees (1)—*Halict.*: Oxystoglossa austrina ♀.

Lepidoptera (1)—*Hesperi.*: Pamphila.

POLYGONACEAE.

Thysanella Fimbriata, Mis., W.—Ninety-six species, 599 individuals observed, N. 11-21. The Lower Hymenoptera are 48.9% of the species and 42.5% of the individuals, while the bees are 17.7% of the species and 40.5% of the individuals. *Odontalictus capitosus,* 1% of the species, showed 17.8% of the individuals.

Long-tongued Bees (6:87)—*Ap.*: Apis sc., 78; *Bomb.*: Bombus impatiens ♂, 3; *Megachil.*: Coelioxys sayi ♂, 1, Megachile lanuginosa ♂ ♀, 3, M. mendica ♂, 1; *Xylocop.*: Xylocopa virginica ♀, 1.

Short-tongued Bees (11:156)—*Collet.* (♀): Colletes sp., sc., 10, C. americanus 1; *Halict.*: Agapostemon ♂, 12, Augochlora fulgida ♂, 1, A. sumptuosa ♀, 1, Chloralictus floridanus ♂ ♀, sc., 12, C. nymphalis ♀, 5, C. reticulatus ♂ ♀, 3, Evylaeus pectoralis ♀, 1, Odontalictus ♂ ♀, sc., 107, in cop., Oxystoglossa austrina ♀, 3.

Other Hymenoptera (48:255)—*Bembic.*: Bembix 1, Bicyrtes insidiatrix 3, B. ventralis 4; *Cercer.*: Cerceris bicornuta 1, C. insolita 4, C. verticalis 1; *Chalcid.*: Leucospis affinis 3, L. slossonae 3; *Crabron.*: Anacrabro robertsoni 1, *type,* Solenius 1; *Eumen.*: Eumenes fraternus 5, E. smithii 3, Leionotus australis 1, L. bifurcus 1, L. fulvipes 1, L. histrio 3, L. molestus 1, L. oculeus 2, L. saecularis 8, L. turpis 1, Odynerus 21;

Larr.: Tachysphex apicalis 2, T. laevifrons 1, Tachytes breviventris 1, T. duplicatus 1, *type*, T. robertsoni 1, *type; Nysson.*: Nysson 3; *Philanth.*: Philanthus carolinensis 27, P. eurynome 1, P. ventilabris 8; *Pompil.*: Allocyphonyx 48, Episyron posterus 1, Pompiloides marginatus 1, P. tropicus 4, Sericopompilus 1; *Sphec.*: Priononyx 11, Sphex gracilis 3, S. nigricans 1, S. pictipennis 1, S. procera 6, S. vulgaris 1; *Scoli.*: Campsomeris plumipes 2, Elis floridanus 36, *type*, E. propodealis 6, *type*, E. robertsoni 3, *type; Vesp.*: Polistes americanus 14, P. rubiginosus 1; *Vipion.*: Cardiocheiles 1.

Diptera (13:34)—*Bombyli.*: Anthrax lateralis 1, A. lucifer 1, Systropus 2; *Conop.*: Conops 1; *Sarcophag.*: Helicobia 1; *Syrph.*: Baccha clavata 6, Orthoneura 1, Volucella fasciata 6; *Tachin.*: Archytas 5, Gonia capitata 2, Phasiopsis 1, Siphosturmia 2, Trichopoda 5.

Lepidoptera (16:57)—*Hesperi.*: Goniurus 4, Hylephila 3, Lerodea 1, Polites baracoa 11, P. brettus 2; *Lycaen.*: Hemiargus 21, Strymon cecrops 1, S. melinus 5; *Nymphal.*: Junonia 1, Phyciodes 1; *Pier.*: Catopsilia 1, Eurema delia 2, E. nicippe 1, Zerene 1; *Satyr.*: Cissia 1; *Syntom.*: Scepsis 1.

Coleoptera (2:9)—*Lampyr.*: Chauliognathus 1; *Scarabae.*: Trichius delta 8.

Hemiptera (1:1)—*Phymat.*: Phymata 1, n.

RHAMNACEAE.

Ceanothus Microphyllus, Pol., W.—Ja. 24-Ap. 14, 178 species and 971 individuals observed Mr. 1-31.

The Lower Hymenoptera show 34% of the species and 42.2% of the individuals; the flies 33.7 and 29.5; the bees 14 and 17. The flowers are pretty decidedly sphecopolytropic. The Diptera and Lepidoptera show a decline in percentage of individuals. The list yields types of 25 new species.

LONG-TONGUED BEES (9:32)—*Epeol.*: Epeolus ♂ ♀, 3; *Megachil.*: Coelioxys 8-dentata ♂, 2, C. sayi ♂ ♀, 9, Megachile generosa ♂, 3, M. lanuginosa ♂, 8, M. mendica ♂, 3; *Nomad.*: Cephen ♂, 2; *Stelid.*: Dianthidium curvatum ♂, 1, D. perplexum ♂, 1.

SHORT-TONGUED BEES (16:134)—*Collet.* (♂ ♀): Colletes distinctus 6, C. thoracicus 40; *Halict.* (♀): Agapostemon 1, Augochlora fulgida 2, A. sumptuosa sc., 21, Chloralictus apopkensis 1, C. ashmeadii 2, C. floridanus 27, C. longiceps 1, C. nymphalis sc., 20, C. reticulatus 1, C. tegularis 1, Evylaeus pectoralis 1, Odontalictus 2, Oxystoglossa austrina 1, *type; Prosopid.*: Prosopis floridana 7, *type.*

OTHER HYMENOPTERA (60:410) — *Cercer.*: Cerceris austrina 47, *type,* C. rufopinta 18, C. verticalis 8; *Chalcid.*: Leucospis affinis 5, L. robertsoni 9, *type,* Orasema 2, Spilochalcis 1; *Chrysid.*: Chrysis 2, Hedychrum 6, Tetrachrysis 6; *Crabron.*: Hypocrabro 5, Solenius 28; *Eumen.*: Eumenes fraternus 8, E. smithii 7, Leionotus apopkensis 3, *type,* L. australis 9, *type,* L. bicornis 5, *type,* L. bifurcus 7, *type,* L. boscii 9, L. foraminatus 7, L. fulvipes 1, L. fundatiformis 1, *type,* L. histrio 9, L. histrionalis 9, L. megaera 1, L. molestus 1, L. oculeus 33, L. saecularis 41, L. turpis 11, Monobia 2, Odynerus 6; *Larr.*: Tachysphex apicalis 2, *type,* T. laevifrons 6, Tachytes aurulentus 4; *Oxybel.*: Oxybelus floridanus 2, *type; Pemphredon.*: Psen maculipes 2, *type; Philanth.*: Philanthus eurynome 22; *Pompil.*: Allocyphonyx 2, Aporinellus 1, Arachnoproctonus 1, Ceropales 1, Episyron biguttatus 9, E. posterus 5, *type,* Planiceps calcaratus 3, *type,* P. dubius 1, *type,* P. minor 1, *type,* Poecilopompilus 2, Pompiloides argenteus 1, P. marginatus 4,

P. subviolaceus 5, Psammochares 1; *Scoli.*: Campsomeris plumipes 8, C. quadrinotata 1; *Sphec.*: Isodontia exornata 2, Psammophila 1, Sphex vulgaris 8; *Tiphi.*: Tiphia floridana 4, *type; Vesp.*: Polistes americanus 2, P. rubiginosus 1; *Vipion.*: Microbracon 1.

Diptera (60:287)—*Agromyz.*: Milichia indecora 21, M. robertsonii 2, *type,* Milichiella 4; *Anthomy.*: Bithoracochaeta 1; *Bibion.*: Dilophus 1; *Bombyli.*: Anthrax lateralis 21, A. lucifer 1, Bombylius 17, Toxophora amphitea 11, T. virgata 2; *Conop.*: Conops 4, Dalmannia 1; *Ephydr.*: Ochthera 1, pred.; *Musc.*: Chrysomyia 2, Synthesiomyia 1; *Sapromyz.*: Pachycerina 2; *Sarcophag.*: Helicobia 9, Metoposarcophaga 1, Ravinia floridensis 1, R. quadrisetosa 15, Sarcophaga assidua 1, S. bullata 1, S. incerta 1, S. utilis 1; *Syrph.*: Allograpta 2, Baccha tarchetius 1, Mesogramma boscii 1, M. marginata 5, Orthoneura 2, Paragus 2, Spilomyia 1, Volucella fasciata 6, V. vesiculosa 1, Xylota 2; *Taban.*: Tabanus 4; *Tachin.*: Archytas 3, Atrophopalpus angusticornis 2, *type,* Atrophopoda 1, Chaetoglossa picticornis 7, *type,* C. violae 5, Cylindromyia 3, Ennyomma globosa 4, *type,* Gonia senilis 4, Gymnoprosopa polita 36, *type,* Hypostena floridensis 6, *type,* Masiphya 1, Pachyophthalmus floridensis 6, *type,* Phasoclista 1, Phorocera 1, Plagiprospherysa 6, Polistomyia 1, Senotainia rubriventris 11, S. trilineata 2, Siphoclytia robertsonii 6, *type,* Siphona 13, Siphophyto floridensis 10, *type,* Spallanzania 2, Sturmia 1; *Trypet.*: Neaspilota 2, Urellia 4.

Lepidoptera (21:28)—*Arcti.*: Utetheisa 1; *Hesperi.*: Achalarus 1, Amblyscirtes 1, Cocceius 1, Lerodea 2, Megistias 1, Pamphila 2, Polites baracoa 1, Thanaos juvenalis 1, T. martialis 1, Thorybes 2; *Lycaen.*: Strymon cecrops 1, S. melinus 1; *Nymphal.*: Junonia 2, Phyciodes 1, Vanessa virginiensis 1; *Papilion.*: Papilio troilus 1; *Pier.*: Eurema euterpe 1; *Rhiodin.*: Calephelis 4; *Sesi.*: Synanthedon rubristigma 1, S. geliformis 1.

Coleoptera (7:39)—*Cerambyc.*: Typocerus 18; *Cler.*: Trichodes 1; *Dermest.*: Attagenus 12, Orphilus 4; *Elater.*: Cardiophorus 1; *Lampyr.*: Chauliognathus 1; *Scarabae.*: Euphoria 2.

Hemiptera (5:41)—*Lygae.*: Melanocoryphus 1; *Pentatom.*: Euschistus crassus 7; *Pyrrhocor.*: Arhaphe 2, Largus 22, in cop.; *Reduvi.*: Zelus bilobus 9.

ROSACEAE.

Amygdalus Persica, Ma., R.—Sixteen visitors observed, F. 10.

Long-tongued Bees (1)—*Anthophor.*: Emphoropsis ♂ ♀, fq. Short-tongued Bees (3, ♀)—*Halict.*: Chloralictus longiceps, C. nymphalis, C. tegularis fq. Other Hymenoptera (4)—*Eumen.*: Leionotus histrio, Odynerus fq.; *Scoli.*: Campsomeris plumipes ab., C. quadrinotata. Diptera (4, n.)—*Agromyz.*: Milichiella; *Ortal.*: Euxesta; *Sarcophag.*: Helicobia; *Seps.*: Sepsis. Lepidoptera (4)—*Dana.*: Danaus archippus; *Papilion.*: Papilio philenor, P. polyxenes; *Pier.*: Catopsilia.

Laurocerasus Caroliniana, Mis., W.—First 1000 individuals taken on the flowers, F. 5-Mr. 4, follow:

Long-tongued Bees (96)—*Anthophor.* 1, Ap. 95. Short-tongued Bees (573)—*Andren.* 527, *Collet.* 21, *Halict.* 25. Other Hymenoptera (13)—*Chalcid.* 4, *Eumen.* 7, *Larr.* 1, *Vesp.* 1. Diptera (288)—Acalyptratae 11, *Anthomy*, 29, *Bibion.* 1, *Conop.* 1, *Musc.* 118, *Sarcophag.* 32, *Syrph.* 74, *Tachin.* 22. Lepidoptera (30)—*Rhopalocera* 29, *Heterocera* 1.

Opandrena scutellaris ♂ ♀, sc., showed 52.7% of the individuals and is probably more important than all of the rest together.

PADUS SEROTINA, Mis., W.—F. 3-Ap. 2, 29 species, 102 individuals observed, Mr. 14, 15.

LONG-TONGUED BEES (1:15)—*Ap.*: Apis sc., 15. SHORT-TONGUED BEES (4:7, ♀)—*Collet.*: Colletes sp. 1; *Halict.* (sc.): Agapostemon 3, Chloralictus reticulatus 1, C. tegularis 2. OTHER HYMENOPTERA (3:14)—*Sphec.*: Chalybion 1; *Scoli.*: Campsomeris plumipes 4, C. quadrinotata 9. DIPTERA (14:40)—*Anthomy.*: Limnophora 1; *Bombyli.*: Bombylius 2; *Conop.*: Zodion 3; *Musc.*: Chrysomyia 20, Lucilia caesar 1, Musca 1; *Stratiomy.*: Nemotelus 1, Odontomyia cincta 1, O. trivittata 1; *Syrph.*: Allograpta 1, Eristalis dimidiatus 1, Helophilus similis 1, Psilota 1, Tropidia 5, in cop. LEPIDOPTERA (6:23)—*Hesperi.*: Achalarus 2, Polites baracoa 10; *Nymphal.*: Junonia 2, *Papilion.*: Papilio cresphontes 2, P. marcellus 2, P. philenor 5. COLEOPTERA (1:3)—*Lampyr.*: Chauliognathus 3.

PRUNUS UMBELLATA, Mis., W.—Ja. 18-Mr. 16, 89 visitors observed F. 8-14.

LONG-TONGUED BEES (5)—*Anthophor.*: Emphoropsis ♂ ♀, ab.; *Ap.*: Apis. sc., ab.; *Bomb.*: Bombias scutellaris ♀; *Xylocop.* (♂ ♀): Xylocopa micans, X. virginica sc., fq.

SHORT-TONGUED BEES (11)—*Andren.*: Opandrena scutellaris ♂ ♀, sc., in cop., *type; Halict.* (♀): Agapostemon, Chloralictus apopkensis sc., *type,* C. ashmeadii sc., *type,* C. longiceps, *type,* C. nymphalis sc., C. reticulatus sc., *type,* C. tegularis sc., Evylaeus pectoralis sc., Oxystoglossa matilda, *type; Prosopid.*: Prosopis schwartzii ♂ ♀, ab., in cop.

Other Hymenoptera (13)—*Chrysid.*: Chrysis; *Crabron.*: Solenius; *Eumen.*: Eumenes fraternus, E. smithii ab, Leionotus bifurcus, L. floridanus *type,* L. histrio ab., L. saecularis, Odynerus ab.; *Scoli.*: Campsomeris plumipes; *Vesp.*: Polistes americanus, P. pallipes, P. rubiginosus.

Diptera (32) — *Agromyz.*: Milichiella; *Anthomy.*: Coenosia ovata, C. sexnotata, Limnophora, Phorbia; *Bombyli.*: Anthrax lateralis; *Conop.*: Physocephala, Zodion; *Musc.*: Chrysomyia; *Oscin.*: Siphonella; *Sarcophag.*: Helicobia, Ravinia quadrisetosa, Sarcophaga assidua, Sarcophagula; *Syrph.*: Allograpta, Ceria, Eristalis albiceps, E. transversus, Helophilus similis, Mesogramma marginata ab., Orthoneura, Psilota fq., Syrphus, Tropidia, Volucella fasciata, V. sexpunctata, Xylota fq.; *Tachin.*: Archytas, Hypostena vanderwulpi, Plagiprospherysa, Siphona, Xanthomelana.

Lepidoptera (28)—*Dana.*: Danaus archippus ab.; *Hesperi.*: Epargyreus, Goniurus, Lerodea, Paratrytone, Polites baracoa, Thanaos juvenalis ab., T. martialis; *Lycaen.*: Atlides, Strymon cecrops fq., S. melinus fq.; *Nymphal.*: Dione, Junonia, Phyciodes fq., Vanessa atalanta, V. virginiensis; *Papilion.*: Papilio cresphontes, P. glaucus, P. marcellus ab., P. philenor ab., P. polydamus, P. polyxenes, P. troilus fq.; *Pier.*: Catopsilia, Zerene; *Rhiodin.*: Calephelis; *Arcti.*: Lerina; *Noctu.*: Pachymorpha.

Rubus Villosus, Mi., W.—F. 13-Ap. 26, 6 visitors observed, Mr. 13. The list is fragmentary.

Lepidoptera (6) — *Hesperi.*: Pamphila, Thorybes; *Nymphal.*: Junonia; *Papilion.*: Papilio cresphontes, P. philenor ab., P. troilus.

RUBIACEAE.

Gelsemium Sempervirens, Ma., Y. — The corolla is 30 to 35 mm. long, its five-lobbed border expanding to the same extent. The base is 25 mm. long. From a narrow part below, which is 8 mm. long by 2 mm. wide, it widens regularly to a throat which is 15 mm. wide. The throat within is rich orange.

In the short-styled form the 4 lobed stigma rises 10 mm. The 5 filaments are attached to the corolla for 8 mm., their free ends exposing the anthers 6 mm. beyond the mouth of the tube. The stamens form a central column, the anthers being extrorse. The bee touches the stamens exteriorly and inserts its tongue between the filaments. The stigma lobes project between the filaments. The tube is narrowed by the filaments, the pistil and the stigma. A tongue at least 10 mm. long is necessary to drain the nectar. There is a tendency to sternotribe zygomorphism. The flower is horizontal, the border vertical, the upper lobes somewhat reflexed. The stamens are bent a little upward, and *Emphoropsis* lands upon them and enters on the upper side of the flower.

In the long-styled form the stigma is less exserted than the anthers in the short-styled form and the stamens are longer than the pistil of that form. The tube is obstructed by the anthers. The style is declined toward the lower side.

Self-pollination might be effected by insects in the short-styled form. In the other form it can hardly occur. D. 7-Ap. 3, 5 visitors observed, F. 3-26.

Long-tongued Bees (1)—*Anthophor.*: Emphoropsis ♂ ♀, ab. Lepidoptera (4)—*Hesperi.*: Goniurus; *Papilion*: Papilio philenor; *Pier.*: Catopsilia, Eurema nicippe.

Houstonia Rotundifolia, Ma., W.—The flowers often appear as mats a foot or more in extent, and are quite attractive to insects. The corolla is salver-form, with four ovate white lobes, the tube yellowish. The tube is 6 mm. long and nectar is secreted at its base.

In the short-styled form the stigma stands in the throat, while the stamens rise 3 mm. above. The stamens are separated (3 to 4 mm.), so as to apply pollen to the heads or other parts of the visitors, where it will be readily received by the stigma of the long-styled flower.

The long-styled form can only deposit its pollen on the tongues of the visitors, where it will touch the stigma of the short-styled form. The stigma rises 3 to 4 mm. above the mouth, the anthers being included. The throat is narrowed by the introrse anthers. Ja. 5 to Ap. 26, 28 visitors observed, Ja. 30-F 24.

Short-tongued Bees (1)—*Halict.*: Agapostemon ♂. Other Hymenoptera (1)—*Scoli.*: Campsomeris plumipes. Lepidoptera (26)—*Dana.*: Danaus archippus; *Hesperi.*: Goniurus, Hylephila, Lerodea, Polites baracoa, P. brettus, Prenes, Thanaos juvenalis, T. martialis, T. terentius, Thorybes; *Lycaen.*: Strymon cecrops, S. melinus; *Nymphal.*: Dione, Junonia, Phyciodes, Vanessa virginiensis; *Papilion.*: Papilio marcellus, P. philenor, P. troilus; *Pier.*: Catopsilia, Eurema delia, E. euterpe, E. nicippe, Zerene; *Rhiodin.*: Calephelis.

RUTACEAE.

Fagara Clava-herculis, Mis., Y.—Mr. 16-Ap. 16; first 1000 individuals taken on staminate flowers, Mr. 17-Ap. 2, follow:

Long-tongued Bees (171)—*Anthophor.* 3, *Ap.* 128, *Bomb.* 3, *Epeol.* 1, *Megachil.* 28, *Nomad.* 3, *Stelid.* 3, *Xylocop.* 2. SHORT-TONGUED BEES (683)—*Andren.* 32, *Collet.* 259, *Halict.* 192. OTHER HYMENOPTERA (108)—*Cercer.* 2, *Crabron.* 8, *Eumen.* 37, *Ichneumon.* 1, *Larr.* 1, *Nysson.* 1, *Philanth.* 24, *Pompil.* 5, *Scoli.* 7, *Sphec.* 4, *Tiphi.* 10, *Vesp.* 8. DIPTERA (177)—*Bombyli.* 7, *Conop.* 37, *Musc.* 86, *Syrph.* 15, *Tachin.* 32. LEPIDOPTERA (51)—*Rhopalocera* 50, *Heterocera* 1. COLEOPTERA (6)—*Lampyr.* 6. HEMIPTERA (4)—*Pentatom.* 4.

The Colletidae, about 2.7% of the families, showed 25.9% of the individuals. *Colletes thoracicus* had 256 individuals. The Colletidae, Halictidae and Apidae, about 8.3% of the families, made up 57.9% of the individuals.

SCROPHULARIACEAE.

ILYSANTHES GRANDIFLORA, Ma., R.—The flower is blue, the lobes more or less white, especially at the tips. The upper lip is small and cleft, the lower spreading, with three large rounded lobes. On the lower wall of the corolla the filaments of the two lower sterile stamens form two ridges which are covered with yellow pollen-like glands. The filaments have about the middle an awn-like process.

The stigma lies under the upper lip. The two fertile anthers are coherent and lie on the upper wall about 2 mm. below the stigma. In this position self-pollination is fairly impossible. The insect's tongue touches the stigma before the anthers. The stigma is sensitive and closes after contact.

When the tongue touches the anthers and is withdrawn, it turns back the lower lobe of the stigma and closes it.

The tube is narrow, rendered more so by the sterile filaments, perhaps entirely excluding short tongues and requiring long tongues to incline to the opposite side where they will touch the anthers and stigmas. The tube is about 6 mm.

The flower is *nototribe,* but insects may land on any side and insert their tongues. F. 15-Mr. 23, 4 visitors observed, F. 21-Mr. 7.

SHORT-TONGUED BEES (1)—*Halict.*: Chloralictus ashmeadii ♀, fq. LEPIDOPTERA (3)—*Hesperi.*: Polites baracoa, Thanaos juvenalis; *Nymphal.*: Phyciodes.

LINARIA CANADENSIS, Ma., R. (*2*, 228; *5*, 585)— F. 17-Ap. 26, 31 visitors observed at Orlando and Inverness, F. 17-Mr. 24.

LONG-TONGUED BEES (6)—*Ap.*: Apis; *Megachil.*: Coelioxys sayi ♀, Megachile lanuginosa ♂ ♀, M. mendica ♀; *Nomad.*: Centrias ♀; *Stelid.*: Dianthidium notatum ♂. SHORT-TONGUED BEES (6, ♀)—*Halict.*: Agapostemon, Augochlora fulgida, A. sumptuosa, Chloralictus longiceps *type,* Evylaeus pectoralis, Odontalictus. OTHER HYMENOPTERA (1)—*Scoli.*: Campsomeris quadrinotata. DIPTERA (3)—*Bombyli.*: Toxophora amphitea; *Syrph.* (f., n.): Baccha clavata, Mesogramma marginata. LEPIDOPTERA (15) —*Hesperi.*: Ancyloxypha, Atalopedes, Lerodea, Polites brettus, P. cernes, Prenes; *Nymphal.*: Junonia, Phyciodes, Vanessa virginiensis; *Papilion.*: Papilio marcellus, P. philenor; *Pier.*: Catopsilia, Eurema euterpe, Zerene; *Arcti.*: Utetheisa.

PENTSTEMON HIRSUTUS, Ma., W.—Mr. 30-Ap. 11, 1 visitor observed, Ap. 8.

LONG-TONGUED BEES (1)—*Bomb.*: Bombus americanorum ♀.

SOLANACEAE.

PHYSALIS ARENICOLA, Mi., Y.—Mr. 28-Apr. 29, 1 visitor observed Ap. 6.

Short-tongued Bees (1)—*Collet.*: Colletes latitaris ♂.

Solanum Nigrum, Ma., W.—F. 24-Ap. 29, 1 visitor observed at Orlando, F. 24.

Long-tongued Bees (1)—*Bomb.*: Bombus impatiens, ♀, c.

UMBELLIFERAE.

Hydrocotyle Umbellata, Pol., Y. (4, 456, 459)—F. 27-Ap. 26, 33 species and 65 individuals observed at Orlando, Mr. 15-20.

Short-tongued Bees (1:1)—*Panurg.*: Perdita ♂, 1. Other Hymenoptera (10:18)—*Larr.*: Notogonidea 4, Tachysphex apicalis 1; *Oxybel.*: Oxybelus fulvipes 1, *type; Pompil.*: Anoplius 1, Lophopompilus 1, Pompiloides americanus 4, P. argenteus 3, P. marginatus 1, P. subviolaceus 1; *Tiphi.*: Tiphia vulgaris 1. Diptera (19:41) — *Agromyz.*: Milichiella 1; *Anthomy.*: Bithoracochaeta 1, Homalomyia 1, Limnophora 4; *Musc.*: Chrysomyia 2, Lucilia sericata 1, L. sylvarum 4, Musca 4; *Ortal.*: Tephronota 7; *Oscin.*: Chlorops 1; *Sarcophag.*: Ravinia floridensis 1, Sarcophaga bullata 2; *Syrph.*: Baccha tarchetius 1, Mesogramma boscii 5, M. marginata 2, Microdon viridis 1, *type,* Orthoneura 1; *Tachin.*: Phasioclista 1, Senotainia trilineata 1. Coleoptera (3:5)—*Carab.*: Lebia 1; *Lampyr.*: Chauliognathus 3, Polemius 1.

VERBENACEAE.

Lantana Camara, Mas., Y.—Three visitors observed at Orlando, F. 24.

Lepidoptera (3) — *Hesperi.*: Thanaos juvenalis; *Papilion.*: Papilio marcellus, P. philenor.

Lantana Odorata, Mas., R.—Ja. 24-Ap. 11, 17 visitors observed, F. 16-Mr. 19.

Diptera (1, f, n) — *Syrph.*: Mallota. Lepidoptera (16)—*Dana.*: Danaus archippus; *Hesperi.*: Atrytonopsis, Cocceius, Lerodea, Megistias, Polites baracoa, Thanaos juvenalis; *Nymphal.*: Junonia, Phyciodes, Vanessa virginiensis; *Papilion.*: Papilio cresphontes, P. philenor, P. troilus; *Pier.*: Eurema euterpe, E. nicippe, Zerene.

VIOLACEAE.

Viola Lanceolata, Mi., W. — The flowers are small. The petals are white, the lower one streaked with purple, lateral not bearded. The flower is not adapted to pollen-collecting bees. The spur is short. From the tip of the style a narrow passage leads to the base of the tube, a distance of about 4 mm. The stigma is beaked and only surpasses the anthers a little, but enough to prevent self-pollination.

Insects land on the upper petals and approach the nectary from above. The flower is therefore sternotribe, the place of pollen-contact being the under surface of the proboscis. Ja. 19-Ap. 26, 16 visitors observed, Ja. 19-F. 20.

Short-tongued Bees (3, ♀)—*Halict.*: Chloralictus apopkensis, C. ashmeadii, Odontalictus. Diptera (3)—*Tachin.*: Chaetoglossa picticornis, C. violae fq, *type*, Siphona fq. Lepidoptera (10)—*Hesperi.*: Amblyscirtes, Cocceius, Goniurus, Megistias, Polites baracoa, Thanaos juvenalis; *Nymphal.*: Phyciodes; *Papilion.*: Papilio philenor; *Pier.*: Eurema delia, E. euterpe.

Flower Classes.

Ma.—Non-social long-tongued bee flowers (including 0) are 57.1% of the flowers observed, receive 34.4 and 28.6% of the total and the pollinating visits. The class receives 71% of the pollinating visits of long-tongued bees and 38.2 of those of Lepidoptera. These are respectively 32.4 and 38.9% of the total visits to Ma.

Ma shows for colors R 40.6, Y 25.0 and W 34.3%, and for visits to each color 49.1, 15.7 and 35.1%. Of the total visits to R, Y and W, Ma receives 71.0, 44.3 and 18.9%.

Ma shows maxima of long-tongued bees, 70.5, short-tongued bees 33.6, and Lepidoptera 48.9.

Of total non-pollinating visits, Ma shows 78.4%, of those of Lepidoptera 88.3, flies 75.0, Lower Hymenoptera 71.4 and short-tongued bees 66.6%. Many insects get pollen or nectar without effecting pollination.

Ma shows maxima of Trochil, Anthophor, Bomb, Eucer, Megachil, Stelid, Halict, Bombyli, Hesperi, Nymphal, Papilion, Pier, Scoli, long-tongued bees, total Lepidoptera.

Mi.—The non-social short-tongued bee flowers are 17.8% of the flowers observed and receive 6.2% of the visits. Lepidoptera are 57.4% of the visitors and short-tongued bees 22.2. The Lepidoptera are not better adapted but more common.

The colors are R 10, Y 30 and W 60%, and the visits R 7.4, Y 16.6 and W 75.9. But the percentages of total visits to Mi, R, Y and W are 1.9, 8.4 and 7.4.

Mas.—The social long-tongued bee flowers are 10.7% of the flowers and show 8.4% of the visits. Of the visits to Mas, the Lepidoptera show 53.4%.

Mis.—The social short-tongued bee flowers are 8.9% of the flowers and show 26.4% of the visits. Of the visits to this class, the lower Hymenoptera show a maximum of 28.2%, the flies with 27.0 and the Lepidoptera with 23.1. Of the visits of the flies, lower Hymenoptera and short-tongued bees, 39.9, 36.5 and 28.8 are to this class.

Mis shows maxima of Xylocop, Collet, Lycaen, Sphec, Bembic, Crabron, Philanth, Syrph, Conop, Stratiomyidae.

Pol.—The polytropic flowers are 5.3% of the flowers and receive 24.4% of the visits. Of the visits to this class, the flies show a maximum of 37.2, the lower Hymenoptera with 33.4. Of the visits of the flies and lower Hymenoptera 47.0 and 39.8% fall under Pol.

Cases referred to Pol on account of the species of visitors may be shown to belong to Mis when the individuals are counted. In *Fagara clava-herculis* the short-tongued bees forming 9.3% of the families, were 48.5% of the individuals.

Pol shows maxima of Eumen, Pompil, Oxybel, Tiphi, non-aculeata; Tachin, other Calyptratae, total Muscoidea, total flies, lower Hymenoptera, Coleoptera, Hemiptera.

Social and non-social flowers.—While the social (Mas, Mis, Pol) are only 25% of the flowers observed by me at Inverness and Orlando, they receive 59.2% of the visits. Of 437 flowers observed at Carlinville, Illinois (*8*, 158), the social, 45.4% of the total, received 78.9% of 13,971 pollinating visits. The differences are 34.2 and 33.5.

Colors.

Red.—Red flowers are 32.1% of the flowers observed and receive 23.8% of the visits. Of the visits to red, the Lepidoptera made 49.2%. Red shows maxima of Eucer and Megachilidae.

Yellow.—Shows 25% of the flowers observed and 12.1% of the visits. Of the visits to yellow, 23.8% are made by flies and 23.8 by Lepidoptera.

White—Shows 42.8% of the flowers and 64% of the visits. The lower Hymenoptera show 84.2, flies 76.7, Coleoptera and Hemiptera 64.5, short-tongued bees 56.7, Lepidoptera 54.9, long-tongued bees 41.1% under white, all maxima. Of total visits to white, the Lepidoptera show 27.9%, lower Hymenoptera 27.0, flies 23.2, short-tongued bees 10.6, long-tongued 7.5.

General colors.—As we pass from red through yellow to white, the long-tongued bees show 38.2, 20.5, 41.1; Lepidoptera 36.1, 8.8, 54.9; short-tongued bees 25.9, 17.3, 56.7; Coleoptera and Hemiptera 12.9, 22.5, 64.5; lower Hymenopetera 10.7, 5.0, 84.2; flies 8.3, 14.8, 76.7. Or long-tongued bees and Lepidoptera 36.7, 11.9, 51.3; other insects 13.3, 12.2, 74.4. The determining condition is that red generally shows the deepest seated nectar and white the shallowest. At Carlinville, Illinois, were observed 13,971 pollinating visits to 437 flowers, of which 30.2% were red, 30.6 yellow and 39.1 white. Long-tongued bees show 34.0, 31.4, 34.5; Lepidoptera 36.8, 23.7, 39.3; short-tongued bees 11.9, 35.8, 52.1; flies 7.7, 32.9, 59.3; lower Hymenoptera 7.5, 29.4, 62.9; Coleoptera and Hemiptera 6.3, 31.3, 62.2. Long-tongued bees and Lepidoptera show 34.6, 29.2, 36.0; other insects 8.9, 32.9, 58.0.

Species and individuals.—In the case of 18 species in which the individual insects were taken as they came, bees shows 24.9% of 477 pollinating visits and 37.4% of 2,679 individuals. In the case of 41 flower species observed at Carlinville, Illinois, bees were 31.6% of 405 species, made 40.2% of 1,452 visits and were 57.4% of 7,391 individuals (*9*: 70.)

INSECTS.

Long-tongued bees.—In the case of 338 visitors and 867 visits, the long-tongued bees show 8.8% of the species and 11.7% of the visits; 13% of the pollinating and 1.9% of the non-pollinating. The maximum is 70.5% under Ma. For colors, they show 38.2% to red and 41.1 to white, or 6.1 more and 1.7 less than the percentages of colored flowers observed. The Megachil, Bomb and Anthophor, 33.3, 13.3 and 6.6% of the long-tongued bees, make 44.1, 14.7 and 11.7% of the long-tongued bee visits. These, with Eucer and Stelid, have maxima under Ma. The Xylocopidae show maxima under Mis.

Short-tongued bees.—Being 7.9% of the species, these show 11.9% of the visits; 12.4% of pollinating and 8.8 of non-pollinating visits. The maximum is 33.6 under Ma. They show 25.9% to red and 56.7 to white, or 6.2% less and 13.9 more than the percentages of those colors. All of their non-pollinating visits are to red flowers for which they are too small.

The Halict, 59.2% of the short-tongued bees, make 85.5% of the short-tongued bee visits. They show maxima under Ma. The Collet show maxima under Mis.

Lower Hymenoptera.—Being 29.5% of the visitors they make only 20.5% of the visits; 21.4% of the pollinating and 13.7 of the non-pollinating. A maximum of 39.8% is under Pol. They show 10.7 under red and 84.2 under white, or 21.4 less and 41.4 more than the percentages of those colors. The Eumen., Pompil. and Scoli., 21, 19 and 6% of the lower Hymenoptera, make 27.5, 14.0 and 14.6% of the lower Hymenoptera visits. They show maxima as follows: the Scoli under Ma; the Spec, Bembic, Crabron and Philanth under Mis; the Eumen, Pompil, Oxybel, Tiphi and non-aculeata under Pol.

Flies.—These are 30.7% of the visitors and make 19.3% of the visits; 20.3% of the pollinating and 11.7 of the non-pollinating. The maximum is 47% under Pol. They show 8.3 under red and 76.7 under white, 23.8 less and 33.9 more than the percentages of those colors.

They show maxima as follows: the Bombyli under Ma; the Syrph, Conop and Stratiomy under Mis; the Muscoidea under Pol. They show in percentages of fly species and visits: Bombyli 6.7, 10.7; Syrph 23.0, 26.7; Tachin 27.8, 23.2; other Calyptratae 14.4, 16.0; total Calyptratae 42.3, 39.1; total Muscoidea 61.7, 54.7.

Lepidoptera.—Are 15.6% of the species and make 32.5% of the visits; 29% of the pollinating and 58.8% of the non-pollinating. The maximum is 48.9% under Ma. They show 36.1 under red and 54.9 under white, or 4 and 12.1 more than the percentages of those colors. Of the non-pollinating visits 80% are to red. These show percentages of Lepidoptera species and visits: Hesperi 41.5, 44.6; Papilion 13.2, 18.7; Nymphal 9.4; 12.7; Pier 9.4, 12.4. These families show maxima under Ma. The Lycaen show maxima under Mis.

Coleoptera and Hemiptera.—Are 6.8% of the visitors and make 3.5% of the visits. The maximum of 48.3% is under Pol. They show 12.9% under red and 64.5 under white, or 19.2 less and 21.7 more than the percentages of those colors.

Early visits at Inverness and Carlinville.—Comparing percentages of the visits observed at Inverness, Ja.-Ap., with those observed at Carlinville before July shows some remarkable results. The Lepidoptera are the most conspicuous with 29 against 6.4. The lower Hymenoptera show 21.4 and 10.1, resembling the late visits at Carlinville, 22.7. The lower Hymenoptera and Lepidoptera make 51.7% of the early visits at Inverness and only 16.5% of those at Carlinville.

The short-tongued bees show 12.4 and 27.7, while the long-tongued show 13.0 and 20.7. The bees make 48.5% of the early visits at Carlinville and 25.4% of those at Inverness. The short-tongued bees and flies make 56.9% of the early visits at Carlinville and 32.8% of those at Inverness.

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FIELD STUDIES IN THE BEHAVIOR OF THE NON-SOCIAL WASPS

PHIL RAU

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FIELD STUDIES IN THE BEHAVIOR OF THE NON-SOCIAL WASPS

PHIL RAU

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INTRODUCTION.

This work on the behavior of twenty-three species of solitary wasps was all done in the vicinity of St. Louis, Mo., between the years 1917 and 1923.

As in previous studies, all insect material was submitted to experts for identification, and their names appear in brackets throughout the work. The photographs were made by the author, and the drawings were made by Dr. Gustave Dahms of this city. A debt of gratitude is due to my wife for valuable assistance on the manuscript.

"Observation sets the problem; experiment solves it, always presuming that it can be solved, or at least if powerless to yield the full light of truth, it sheds a certain gleam over the edges of the impenetrable cloud."

—J. H. FABRE.

"So the first task of comparative psychology is to find out the instinctive equipment of any animal studied. Instincts are, however, well worth study for their own sake. An instinctive fear of a certain enemy may be as truly useful to an animal as sharp teeth or protective coloration. Instincts are the expression of structures and functions of the nervous system, and are as real and as important matters for the biologist as are bones and blood vessels."

—E. L. THORNDIKE.

"It may be noted that all the activities of ants, their reflexes and instincts as well as their plastic behavior, gain in precision with repetition. In other words, all their activities may be secondarily mechanized to form habits, in the restricted sense of the word. This is tantamount to say that even the reflexes and instincts are not so stereotyped but that they may become more so by exercise during the lifetime of the individual. And not only do ants thus form habits, but . . . these habits when once formed are often hard to break. It is certain that many instincts . . . are at first complete and indefinite and are guided to their proper course by stimuli that affects the organism at a later period. . . . . There is little doubt, moreover, that the more fixed or stereotyped instincts are phylogenetically the older."

—WM. M. WHEELER.

CHAPTER I.

The Life Habits of Two Beetle-hunting Wasps.

The Jerseydale Cerceris, *Cerceris raui* Roh. [S. A. Rohwer].

Jerseydale (fig. 26), some 30 miles south of St. Louis, consists of a railroad sign-post, a milk-can platform, and a well of excellent cold water; this equipment renders it easily recognizable as the center of a thinly populated but prosperous dairying community.

Besides the well, Jerseydale has other attractions, unnoticed perhaps by the men who daily drive up to the platform to exchange their full cans for empty ones. In the hard road under the hoofs and wheels abound the Cerceris wasps, *Cerceris raui.* This wasp (fig. 27) was described by Rohwer from material submitted from three distinct localities: Lake View, Kan.; Wickes, Mo., and Jerseydale, Mo.* While only fragmentary notes were gathered from the first two localities, at Jerseydale the life secrets of this species were more fully discovered.

One salient feature of their habits is that in all three places their nests were dug chiefly in the hard-packed roads, where traffic was heavy, and only a very few nests on the outskirts of a colony occurred at the roadside.

The hole which this species makes is an excellent piece of workmanship. There is no attempt at concealment of the burrow, such as we find practiced, sometimes very skillfully, by some other species of wasps. Her nest is so inaccessible in its situation that she can well afford to work boldly and openly before all men, without fear of her home being molested, unless by parasites which are cunning enough to elude her and gain access by her own doorway. The burrows in each of the three habitats

*Also taken later at Wesco, Mo., 108 miles west of St. Louis.

were found in the middle of a well-beaten road, where the earth was so hard packed as to be almost impenetrable with ordinary tools. A spading-fork, a digging-trowel and a pruning-knife each in turn proved ineffectual in the conquest, and only by the aid of a hatchet was I finally able to follow a very few burrows to their termini. The work was rendered increasingly difficult by the fact that the nests were in the beaten track, and at the approach of each automobile or wagon it was necessary for the perspiring investigator to take flight to a safe distance to escape the wrath of the irate drivers who seemed not to appreciate the beauty of the quest of truth when it led to the digging of chuck-holes in their roadway. At Lake View the road leading to a country club was beaten so hard by the automobile traffic that I could not dig up a single nest. At Jerseydale the yellow clay was very sticky when wet and flinty when dry, and at Wicks (fig. 28) the admixture of clay and rocks rendered digging most difficult. At the two latter places, however, a few nests were found at the side of the road which could be dug out to sufficient depths to learn some details of their interiors.

The mouth of the hole is always beautiful in its symmetry; it is ½ inch in diameter, and around the aperture is a mound of chips or granules of earth which have been brought up from below (see fig. 29; a ten-cent coin nearby shows the relative size). The burrow is amply large; the diameter is sufficient to permit the occupant easily to turn around or even to make her toilet while within. The tunnel is long and tortuous. In the places where rocks are present in the soil this is, of course, the logical result, but the same condition exists to an extreme degree in clear soils also. The illustration (fig. 30, ¼ nat. size) gives an idea of the rambling course of one of these channels, but, of course, an incomplete idea, since a diagram can show the curves in only one plane, and not the curves toward and away from the observer. Another was described in detail in my notes as follows: This hole went straight down for 2 inches, then curved toward the southeast for 3 inches, then southwest for 4 inches, made a sharp turn toward the northwest and downward for 4 inches, westward and still down for 2 inches, upward and west 2 inches, then curving downward and south about 4 inches. Along this section of the tunnel were three cells containing fat *Cerceris* larvae and beetle remains. These cells were oval and about 1¼ inches long and ¾ inch in diameter. Beyond this the tunnel continued slightly upward and westward for 3 inches more, and in the end, in a sort of pocket, were 3 more fat beetles. This indicates that the wasp digs her tunnel and makes several pockets at the terminus for brood cells. The tunnel varied slightly in diameter, the minimum being about ½ inch. The total length of this one was 24 inches, and the cells were situated 17 inches below the surface of the ground. One can readily see what an enormous task this mother wasp had accomplished, to have made so large an excavation in soil which was so nearly impenetrable that I myself could hardly dig it.

The excavation of another burrow was begun in the absence of the mother wasp. The hole was likewise very tortuous, and at a depth of 15 inches it turned directly under the hardest part of the road, where the tools broke and the digging had to be abandoned. Meanwhile the mother returned, and so persistent was she in trying to enter the wreck of her home that twice I picked her up in the forceps with perfect ease. She fairly fought to get back to the place, and dug for more than an hour trying to follow her old burrow, which she recognized so surely despite its mutilation. I left her still working feverishly at her task of reconstruction.

Since in the three places where these wasps have been found they occurred in settlements or colonies, one wonders if they do not dig their way out of their subterranean winter dormitory in the spring and then turn around and enlarge their exit-passage for their new burrows. It seems incredible that one wasp is able to dig so large a tunnel in so short a time.

I earnestly hope that the reader will be satisfied with the details of these few burrows, so I may mercifully be spared the task of digging out another one. So far as I could learn from others partly excavated, the tortuous course and the dimensions of these are fairly typical.

I have not been so fortunate as to see the beginning of the digging of the burrow. Later on in the process, however, when the tunnel was only being enlarged or extended, I have observed the outward evidence of work going on within. There is then little display to attract the attention of the passer-by; the wasp in her dark tunnel down under the earth digs up the soil—I know not how—and packing a considerable mass behind her body and above her in the tunnel, backs up and pushes it out above the surface with her abdomen. This soil comes out, not in loose, powdery form, but in granules packed together to form plugs or sausage-like masses, which protrude for a time above the surface and later, when thoroughly dry, collapse in a heap at a touch or breeze. This digging was observed several times early in the day, before the wasps had come out of their holes to brush back the dirt from around the mouth of the burrows, and depart for refreshments or prey. Hence I cannot say with fairness that these *Cerceris* are not early risers, for I do not know how early they begin their work in the dark gallery, but they do not open up their doors, which are closed each night, until the sun is high and hot in the summer sky. This statement implies that they sleep in their burrows, and so they do; at least the females of the population which possess burrows sleep there; I have not yet been able to find, by careful scrutiny of the vicinity, where the males find their night's lodging. I have never yet seen the males enter the burrows, although they are frequently to be seen pursuing the females as they come and go. They are small and agile, and difficult to apprehend. The sexes are so different in appearance that they look like two different species, the female a large, reddish-colored insect, and the other much smaller and yellow. Mating occurs on the wing or while the home-maker goes to and fro about her work; no special frolic or festival has been observed to accompany this function, such as occurs in several species of wasps.

The owners of the burrows come home and enter the nest early, about 3:30 to 4:30 o'clock, and push up a plug of loose earth to close their door snugly for the night. This roof remains in position remarkably well, in spite of the fact that it is so soft that it will collapse if tickled with a straw. On one afternoon when a shower occurred early, I visited the colony and was surprised to find that even at that time of day, which is usually the wasps' busy hour, these good housewives had all hurried home to shut up the house before the storm broke; every door of the fifty or sixty nests was closed from within!

In covering the hole the wasp backs up with the abdomen extended straight and the load of earth under the abdomen and behind the legs. Thus she pushes the load up to a point ¼ inch from the top, where she presses the dirt against one side of the hole. Thus she brings up a few more loads, condensing and packing the earth against one wall; then she brings up more dirt to close the remaining aperture. Even then she does not stop, but adds many layers to the plug from the inside; we are made aware of this by the movement of the plug as it heaves up with the vigorous pressure from underneath as each load is packed in place. In many cases the wasps seem to deem their day's work done at 4 o'clock, and by 6 most of the holes are partly or completely closed for the night.

It is a pretty sight in the morning to see the wasp first venturing out. The granules of clay covering the hole quiver and part, the head appears, and the opening is silently made wider. Then the wasp pauses to peer cautiously about (fig. 31); this habit of cautious reconnaissance is a very characteristic gesture of this species. She creeps so stealthily to the edge of the hole that one is hardly aware of the motion, and pauses with her face at the aperture and peers about with a gaze so intent that one can almost feel it; if she is not satisfied that all is safe, she drops stealthily back; if all is well, she darts away like a flash, leaving the burrow wide open. She has retreated thus when I moved noiselessly at a distance of 4 feet; this would indicate that her range of vision encompasses at least that distance. Upon returning home, she seems to have no trouble in locating her burrow, although it is one among so many all alike, in the roadway or in the sparse grasses nearby. She does not loiter, but plunges headlong into the burrow, almost before one has time to get a good view of her. Sometimes she circles about on the wing a few times before she seems to get her bearings to make an accurate descent directly upon her burrow.

Every observation upon the *Cerceris raui* population at Jerseydale indicated that this wasp uses only two species of Coleoptera as food for her young, *viz.*, a short, fat weevil, *Thecesternus humeralis* Say [E. A. Schwarz], and the long, slim weevils, *Lixus concavus* Say [E. A. Schwarz] (fig. 32). Less extensive observations at Lake View, Kan., and Wickes, Mo., gave the same results, but the data there were not sufficient to be conclusive. Of 22 females which were caught as they returned to the nest, 16 carried *Thecesternus humeralis,* and 6 had the long, slender beetles, *Lixus concavus.* In the several brood-cells which I had the good fortune to explore, the former beetles were present in far greater numbers. In some cells all the provision was of that species. About 15 to 22 beetles seems to be the ration allowed each young wasp.

In all of the cells wherein the larva had already worked over the food supply provided for it, we found that it had separated each beetle into the three component parts, the head, thorax and abdomen. The head separates easily from the thorax in these beetles, and the larva undoubtedly takes its first meal from the soft tissues at the point where the thorax joins the abdomen. It is wonderful to see how clean these beetle shells have been licked when the larva is done with them. (Fig. 33 shows the beetle remains after the feast). One wonders how it is possible for the larva to clean out the contents so completely without breaking through the body wall at various places, but when one sees the remarkable adaptation of its anatomy for just this purpose, one can readily see how it succeeds in reaching all parts of the body cavity. While it in general looks like all wasp larva, the oral end tapers into a nice point so that it is possible for this part to enter the abdomen through one opening and reach clear to the other end. The head part sways from side to side, and the jaws move about seeking the food when it is taken from them.

The beetles, when they are removed from the cells, are motionless, but if they are taken from the mother wasp as she brings them in, and placed in a vial, they soon revive so that they climb over one another very actively. Hence one doubts if they have actually been stung. The 22 taken from the wasp mothers, as previously stated, were very active when examined the same day; when inspected two days later there was much excrement in the vials, indicating that life had continued for some time, but the beetles were dead; whether death had been due to the confinement or the sting, I do not know. Close observation has taught me that these wasps do sometimes sting their prey, but how general this habit is has not been ascertained. One of them stung a live weevil which I substituted for her own, while another did not. When the wasp was out foraging I placed a small ball of cotton in the mouth of her burrow; when she returned and attempted to enter, she dropped her prey in alarm and flew away, and when she returned she found I had removed the plug. Meanwhile I had also exchanged her quiet weevil for a live one, which was so active that I could hardly keep it near the hole. The mother returned, flew directly into the hole as usual, and after a few seconds crept to the top, poked her head out cautiously, grasped the beetle in her jaws and dragged it in; if a sting was administered it must have been done underground.

Many wasps, in foraging or bringing in building material, take a direct flight to and from the place of interest, either with or without circles of orientation. This species, so far as I have observed, follows a rather strange course; she does not fly "as a bird flies," or "in a bee line," but she literally makes a round trip. Several which I watched going to the cornfield on the other side of the railroad track, left the nest flying northward; after fifty feet or so they circled around toward the east, and after an absence of from 3 to 8 minutes they came back with their prey, by way of the south. Just how general this habit of circular flight is I do not know.

They work with surprising rapidity in bringing in their victims. I timed a number of them on different occasions and they usually took only 3 to 8 minutes to capture a beetle and return. They lost no time in finding the open nest, plunged in, and stored the booty speedily.

It was noticed that practically all of the weevils brought in by these *Cerceris* were covered with a crust of earth. That raises the question: do these beetles occupy subterranean habitations where these wasps are obliged to dig for them? The wasps seem to find them so easily and in such large numbers that there must be an abundant supply of them near, perhaps in the cornfield. To ascertain the hunting habits of these wasps one ought to know something of the two species of beetles that they hunt, *Lixus concavus,* properly known as the rhubarb curculio, and *Thecesternus humeralis.* Of the latter species, Mr. E. A. Schwarz writes: "The life history of this weevil still remains unknown, but the imago is quite common under dried cow dung in our prairie states, or under stones in dry situations in Indiana, western Missouri, Nebraska, Colorado, New Mexico and Texas. Most of the specimens in our collection are covered with a thick crust of dirt, which shows that the earlier stages are passed underground and that the larvae will be found in the roots of some plants. Occasionally specimens of the imago have been found above ground on the stems of various plants. * * * A somewhat allied species, *Rhigopridius tucumanus* Heller, from Argentina, has been bred from the tuber of a potato.''

The weevil makes so small a burden that the *Cerceris* can carry it very easily and swiftly. In all of the cases which I could observe closely, the wasp carried the prey, clasped in her middle legs, with the ventral side of the weevil against the under side of her own body, and in some cases it appeared that she grasped its proboscis in her jaws. She drops her burden quickly if disturbed. One wasp returned with her weevil under her body, and as she found difficulty in finding her hole, which had accidentally been covered, I pressed close to see her method of search. She braced herself with her hind feet while she dug in the mound of dust with her free fore-feet. Not gaining much headway in this manner, she dropped her weevil and then worked faster with four feet. Thus she eventually found her hole on the other side of the mound. Meanwhile, I exchanged the weevil which she had laid down, for one borrowed from another wasp. Several times she went into the hole, as if to make sure that everything was right, and came out again. At last she approached the weevil, took it in her mouth, rolled over and stung it. In my eagerness I came too close and frightened her away. After ten minutes more of nervous coming and going, she again took the weevil in her mouth, curled her body almost into a circle in order to reach the prey with her sting, propping herself up meanwhile on her two protruding wings, while she inserted her sting on the ventral side of the victim and kept it there for almost a minute, her abdomen pulsating all the time. All this happened on the mound of loose soil, only a half inch from her hole, which was now open; nevertheless she took up her weevil, flew into the air, circled about a few times, alighted again in the normal manner and plunged in.

While another nest was being observed, a troublesome weed that grew near it was pulled up; this changed the topography of this tiny area. Upon returning several hours later we found four weevils lying out on top of the ground, and the returning wasp even then circled and buzzed about the hole for fully half an hour before she would enter. It was evident that she had discarded the weevils lying there in the sun; either she had dropped them as she had come back from foraging and had lost them in her confusion at finding the familiar landmarks altered, or she had suspected that, since the region had been changed, her nest had probably been meddled with and so, like other wasps of our acquaintance, she had thrown out the stores she already had as though they were contaminated.

One nest was especially conspicuous because at that point in the road the surface of the ground was covered with black cinders, while the circular mound of subsoil around the hole was gray. This contrast made the nest itself a conspicuous landmark for the returning wasp. I watched until the wasp left home; then with the point of the trowel I carefully removed this gray earth and replaced it with a mound of black cinders, just like the surrounding medium. I was quite proud of my new accomplishment of building wasps' nests, for the imitation was, to my eye, very accurate except for the color of the material. It was, of necessity, a hasty job, for the rightful proprietor returned from her trip in only two minutes. She flew direct to the location of her hole as usual, but just above it she brought herself up with a jerk and flew to and fro over it in an agitated manner for several minutes. Her confusion was evident; twice she dipped down on the wing as if ready to enter, then withdrew in alarm; again she tried to scrape away the cinders a little to one side, as if thinking that her burrow had been covered by accident, as frequently happens during the mother's absence. Thus she continued to search in all the crevices and possible places. For the first five minutes of this hunt, she carried her prey with her; then she dropped it until she could find her burrow. After that she searched on foot thoroughly over all the area within a dozen inches of her hole, only occasionally wandering in circular flights over a wider area. She seemed sure of the general region—the cinder area—but the ring of gray dust around her hole was not to be found; therefore she did not recognize it as her own even after poking her head in three times, and went back to scratch among the cinders in various points for another quarter of an hour. After she had spent a full half hour in this faithful search, I tried to make reparation by bringing a trowelful of gray dust of just the right shade and fineness and putting it nicely around the hole. As soon as I withdrew she returned on the wing to continue the search, and as she came within sight of the place, she dashed straight to it and tumbled in headlong, in the old familiar manner! She remained in longer than usual this time, then passed out and in several times, making short flights of orientation about the place each time. Her faith had been severely shaken and she had to reassure herself many times. Furthermore, things were not yet just as they should be; my clumsy hand had spilled some cinders in her burrow, and she had to make the necessary corrections and get acquainted with the place anew. At last, with one more careful flight of orientation, she departed for the fields to resume her foraging.

These wasps keep so diligently to their nesting business that I have found little else to record concerning them. They neither loiter nor dance, fraternize nor fight. Only a few times during the summer were they seen feeding quietly on the flowers of buckbrush and goldenrod near their nests.

The wasps continued to work the old burrows until late in the summer, but no new ones appeared during the latter part of the season. They continued to push up dirt and carry in prey; hence I surmised that they were extending the burrows and putting in additional pockets. During the week of September 12-18 they disappeared; the earth over their holes was soon beaten down by rain and traffic. The place and manner of their death was not learned.

A number of other species were seen prowling about the premises of *Cerceris'* home. Their purposes or methods of approach were not actually ascertained, but we know the character of some of them well enough to feel justified in holding our suspicions. A *Parametopia sp.* entered one hole and was captured as it emerged. In early August many *Hedychrum violaceum* Brulle [S. A. Rohwer] (fig. 34) were seen entering the burrows, and in two instances *Lyroda sublita* Say [S. A. Rohwer] intruded. A *Megachile* was also seen hovering about the burrows of *Cerceris,* but I could not catch her in any misdemeanor. Several specimens of the Dipteron, *Exoprosopa fasciata* Macq. [C. T. Greene] were taken as they persistently hovered above the *Cerceris* burrow at Jerseydale.

The Bill-bug Huntress, *Cerceris bicornuta* Guerin [S. A. Rohwer].

Cerceris bicornuta, like *C. raui,* digs holes in the earth and uses bill-bug beetles for food. The various species of *Cerceris* do not all have the same habits; there is much diversity within the genus, in both nesting sites and prey captured. While most members of the genus nest in the ground, we have a few that make nests in twigs, e. g., *C. finitima* Cress., and in getting prey for the young, certain species catch weevils, Buprestid and other beetles, while others seek bees.

If there are such things as plant societies, then surely we may say insect societies exist. When one compares the wasp population of our baseball diamond at St. Louis with that of the school yard at Pevely, thirty miles distant, then one must surely say that certain types of areas attract certain insect societies. The two places gave us *Bembix nubilipennis, Odynerus dorsale, Cerceris bicornuta,* and one single specimen at each place of *Cerceris fumipennis.* The proportion of each species in the population as a whole was likewise similar.

One frequently finds the hole of this wasp closed when the digging is still in progress, but it is easily located and partially identified by a pile of loose dirt over it (fig. 35), at the center of which is usually a group of a half dozen rolls of dust, tightly packed, just as the wasp has pushed it out of the burrow. This detail indicates that her method of excavating is similar to that of *C. raui.* She digs and pushes the dirt up to the upper part of the channel where it forms a plug; when at intervals she pushes this whole stopper out above the ground the masses of dirt retain their sausage-like form for a time after they have been forced out, until they become thoroughly dry and crumble to dust in the wind. Certain beetles excavate in the same way. It seems that excavating and provisioning must be carried on at the same time, for often when she pushes out a pack of dirt, she throws out some of the bill-bugs as well. Four beetles were found in the dust on the top of one of these nests. These weevils "play possum," and one cannot always tell whether they are dead from the sting or merely in a feint, but these showed no indication of life, even when they were pinned without the usual formalities of a cyanide bottle.

These wasps dig with surprising rapidity. In one nest where the loose dust on the surface was brushed away at 7 o'clock one evening, the next morning at 9 there was a mound of earth 2 inches in diameter and ¾ inch high which had been newly thrown out of the burrow. It seemed impossible that this mound could have been thrown up since daylight; hence I suspect that the mother *Cerceris* had been at work during the night. After all, how can they tell day from night when they are at work in the inky darkness of their underground tunnels?

Rain works real hardship to these little creatures. One of my records tells of a nest in which the work was progressing nicely, and each morning showed a mound of fresh dirt on the surface. A steady rain soon flattened the mound, but the plug held for several hours; a downpour eventually washed it down, however, and the hole was flooded. The next day I watched the nest and concluded that the owner had been drowned, for during several hours of sunshine she did not appear. In the middle of the afternoon, however, I saw her again carrying in her catch of bill-bugs! How she could have escaped death by drowning I cannot see. In other nests which we watched, however, the plugs were soon washed down; the occupants of most of these nests never reappeared. Three survivors tried to rebuild their homes, but were defeated by heavy rains. Thus we see that the rain here was a factor in exterminating the adult population; how the young fared in these circumstances we do not know.

After the excavating is once done, the workers seem to have no objection to leaving the mouth of the burrow open. They are frequently to be seen on sunny days, with the face just within the aperture of the hole, their bright eyes shining as they gaze into the outer world. But if one comes too near, they, like *C. raui*, creep down, cautiously, almost imperceptibly; one does not realize that they are moving until they have vanished from sight.

While *Cerceris bicornuta* persistently chooses for her nesting site a hard-packed soil, yet a number of times I have found evidence that she gladly avails herself of assistance in her digging by utilizing some hole already begun. In one case, one extended a neat hole left by a peg which had been driven into the ground and pulled out. In other instances they used and lengthened the old holes from which *Bembix nubilipennis* had emerged (fig. 36). While they do not seem actually to follow up the *Bembix* or depend upon them for their assistance, they frequently have the opportunity of availing themselves of it, since their choice of the same environment often brings them together.

When one finds insects established in a city lot, one is inclined to think of them as relics from a precivilization period, clinging to their former habitat despite the tightening about them of urban conditions; one is surprised to learn that species new to the neighborhood are coming in and becoming established under our very eyes. Intensive Hymenoptera collecting in this vicinity for eleven years had not revealed one specimen of this wasp. The small area where they are now established was during the four years, 1913 to 1916, subjected to my very intensive study; observations were made almost every day as I crossed the field, yet I never found a single specimen of *C. bicornuta.* In 1917 I was out of the city, and the next summer, on June 30, the first specimen was captured; during the following week six others were found nesting there. This shows how quickly and firmly they become established when they find a desirable environment.

C. bicornuta preys upon three species of bill-bugs, *Sphenophorus placidus, S. zeae* and *S. parvulus.* Bill-bugs are very destructive to cereal and forage crops, and the *Cerceris* wasps are one of the important natural checks. The blue-green bill-bug, *S. parvulus,* is a widely distributed upland species usually infesting timothy and bluegrass, but often injuring wheat, oats, barley and rye. Pupation occurs either in the corms or in the soil.

A large blue cuckoo-bee, *Hedychrum violaceum,* entered the burrow of this wasp and remained within for twenty minutes; what her errand was we can only surmise.

Adults of this species have been found feeding on the flowers of the buckbrush.

CHAPTER II.

An Amputator of Spiders' Legs. *Pseudagenia mellipes* Say [S. A. Rohwer].

The genus *Pseudagenia* belongs to the family Psammocharidae, whose habits of nesting are in rather unstable conditions, since each species shows peculiarities of its own. Natural selection has not, up to the present date, created fixed habits for the genus. There is, however, one department in the work of this genus that has become rigidly established, that is the cutting off of the legs of the spiders stored as food for the young. All species whose habits have been studied show this trait, although in *P. mellipes* (fig. 37) it is possibly not so rigid as in other species, for in numerous cases I have found that only a part of a spider's legs have been removed. As in the genus *Trypoxylon,* we find great versatility of behavior within certain species and within the genus. To Francis X. Williams* falls the credit of having brought to light some highly interesting behavior information on seven species of *Pseudagenia* which were studied in the Philippine Islands, with the aid of which one can point out the evolution of the nesting behavior, from the simple, single mud cells of certain species to that masterpiece of economy, the work of *P. mellipes.*

Versatility in behavior, or adaptability, seem to be the qualities which have led some individuals, at least, of *P. mellipes* to a method of nesting that is most economical of labor, materials and time. In connection with the evolution of the nesting habits of *Pseudagenia,* the following statement by Williams is indeed significant: "The

*Philippine Wasp Studies. Rept. Exp. Sta. Hawaiian Sugar Plant. Assoc., Bull. 14, pp. 79-108, 1919.

genera *Macromeris, Paragenia,* and *Pseudagenia* and others [of the Psammocharidae] are mason wasps, having advanced beyond the digging stage still adhered to by the majority of the family. They build cells of clay or other earth-like material; they may construct these in sheltered or unsheltered places above the ground, more rarely in burrows." As Williams says, "having advanced beyond the digging stage," to a mud-daubing cell-maker, so certain individuals of the species *P. mellipes,* in their cell-making, have gone a step forward in eliminating the carrying of the building materials. We find that in *P. mellipes* this labor-saving method of using materials at hand, or rather of finding the building materials in the shape of a lump of mud plastered on the wall, and then fashioning it into cells, entails the habit of carrying water. This method, when first I discovered it, greatly surprised me, since I thought only the *Odynerus* wasps, and Anthophora bees were capable of so ingenious a method. Since then I have found this same feat done by *Chalybion caeruleum,* which shows at least that this habit can penetrate families regardless of structure (taxonomy). That this water-carrying habit is more deep-seated in the genus than the newly acquired habit of using mud nests already at hand is evidenced by the fact that Williams tells us of a species in the Philippine Islands which follows this method, showing that habit persists in spite of remoteness. Another habit that distance has not obliterated is the method of using the dorsal tip of the abdomen, flexed under the head, as a rounded smoothing tool, in fashioning the nest. This habit we observed also in *Pompiliodes tropicus,** and in Williams' report he records this habit for three species of *Pseudagenia.*

*Wasp Studies Afield, p. 54, 1918.

The stability of these two habits, in groups of organisms separated from each other by half the girth of the earth, lends a tinge of romance to the subject. Shall we say that these habits are instinctive and of so strong a type that they persist regardless of time and space, or shall we rather say that these groups of insects, in the two remote regions, have independently acquired the same habits, through the similarity of their problems or through the similarity of their environment?

I said that in the evolution of nest-building activities, *P. mellipes* is in advance of any other member of the *Pseudagenia* clan, despite the fact that the Philippine *Pseudagenia* are likewise water-carriers and likewise use the abdomen as a tool wherewith to fashion the nest. The facts are that the oriental wasps still carry the building material to the site, while some individuals of our *P. mellipes* have advanced to the point where the carrying proclivities are eliminated. Not all of our *P. mellipes* have abandoned their habit of carrying clay, for we have formerly recorded three and four-celled nests taken from under loose pieces of bark (fig. 40), and a four-celled nest that was found in an oak-apple still hanging on the tree. All of these nests in due season gave forth *P. mellipes*, and both situations certainly entailed the carrying of mud from a distance. Other nests which must have involved the new method of building, have been found in old nests of the pipe-organ wasp, *Trypoxylon politum* (fig. 63), and in the abandoned nests of *Sceliphron caementarium* (fig. 38), where these wasps had built their little cells within the larger ones of both species. Thus we see the most recent accomplishment of the species, that of carrying water, to be so new as not to have permeated the race, and the pioneers in this habit are the wasps observed at an obscure corner of the earth called Wickes.

It is fascinating indeed to think of our own little handful of *P. mellipes* as displaying perhaps a more advanced point in their evolution than other members of even their own species, and exhibiting a type of behavior more advanced than that of any other member of the genus whose habits have been recorded. In this connection we must not overlook one Philippine species, *P. nyemitawa,* whose unique habits are recorded by Williams. This wasp pastes its nest, consisting of two or three cells, on tree trunks, in rather exposed situations, but the structure seems proof against wind and weather, being varnished over with a tree gum. The cells are made of an earth-like substance such as is used by the termites for their coverways. "The wasps first sip up some water from some convenient hollow or edge of stream, and the ball of earth subsequently gathered is worked around in her mouth until it assumes the right consistency, when it is plastered on the building site with the dorsal tip of the abdomen. * * * Before the cell group of two or three cells is completed a partial coat of varnish may be put on. The cells finished are more closely united with mud. * * * When *Pseudagenia* is through with the mud she turns her attention to a tree gum which she works over in her mouth-parts and spreads on precisely as she did the mud. Then without intermission she brings in another final coating or rather patching material—a pale gray lichen—which she works up in her mouth into a sort of viscid paste also applied like mud and varnish, but the nest is blotched rather than completely covered."

There is a small outbuilding at Wickes which harbored a number of old mud nests of *Sceliphron caementarium* in addition to a few nests of *Polistes pallipes.* For two years, 1917 and 1918, the inhabitants therein were objects of study. The ecological succession of life, even in so small a room, was as clear as it was interesting. To recapitulate the story of the occupants, the original builders, *Sceliphron,* had made their nests and left them to the insect community; then the succeeding inhabitants followed in peaceful succession. First after the *Sceliphron* came renters by the name of *Trypoxylon clavatum.* These were abundant, and used the old mud nests with only slight modification. After *T. clavatum* had been watched and studied here for two years, it was suddenly discovered, when the season of 1919 opened, that *clavatum* was no more; that a species never heretofore seen in this building was present in fair numbers, and had taken possession of the situation for its abode. This new citizen in the community, that had the art of making dainty little nests out of old tumble-down, twice-used mud huts, was *Pseudagenia mellipes.*

In previous descriptions and in the paragraphs preceding I have already shown that *P. mellipes* is a fairly versatile little creature. In a former work, when we recorded that this insect was found in the old cells of *Sceliphron* (fig. 38 shows the old nests broken to expose to view the mud cells of *P. mellipes*), and discovered heavy mandible marks on the outside of the nest, we registered the suspicion that this was the work of *P. mellipes.* This suspicion was confirmed by the observation of this lot of little creatures in action. The following extracts from my notebook will give the details.

At 12:50, on September 6, I noticed a one-celled nest of *Sceliphron* with a *P. mellipes* aboard. The opening was half sealed in a manner which was new to me; a wall was being built across the aperture from the two opposite sides, leaving a vertical crack across the center about 5 mm. wide. After five minutes the opening was smaller. My chief attention was at that time concentrated upon other insects; when again at liberty, twenty minutes later, I found the cell completely sealed, and then I ruefully realized that I had lost a rare opportunity to observe this species in action; to find whether she got the mud from elsewhere to seal the aperture, or in some way worked out the mud from various parts of the nests. For the next hour I watched the wasp busy at her work on various parts of the cell, principally at the newly made plug, in a very interesting manner. With her jaws she would scrape very energetically about the rough wall of the shanty, trying apparently to remove some of the surface of the wood, but in reality she was scraping together whatever she could get (often it was mostly dust and spider web) which she worked in her jaws on her way back to the nest a few inches away. When she reached the nest the mouthful was usually applied to the plug which had just been placed. She would press the small ball of dusty web against the plug, flex her abdomen directly under her mouth, emit a tiny globule of water apparently from the anus, and, with the flat-iron movement that we have elsewhere described for *Pompiloides tropicus,* smooth and rub the material into the plug. This she did repeatedly. The rubbish she garnered was a motley mass; it was chiefly dust and spider web, with occasional small splinters, bits of disintegrated insects and vegetation, which, combined with the added moisture, was worked into the nest. Not all of these reinforcements were directed solely to the plug, but many applications were placed promiscuously about the nest.

To see something entirely new in waspdom, and to see it done repeatedly, was indeed enough to hold one alert to catch every detail. To be sure, we had previously discovered that a near relative, *Pompiloides tropicus,* likewise bends the abdomen under the body for the same purpose, and that distant relatives (*Odynerus*) carry water in their throats. These are near approaches to the method now discovered, but are not its counterpart. When I saw that this *P. mellipes* repeatedly left the building by a certain crack, and that when she returned she was able to gather three pellets of reinforcing material, I formed the deduction, based largely on experience with *Odynerus,* that this was also a water-carrying species. Yet the puzzling question remained unanswered: If she fills her crop with water, how does it go through the body so quickly to be emitted from the opposite extremity a few minutes later? The drop of water was each time handled with such lightning speed that, I must confess, I might have been deluded; perhaps the drop came from the mouth, and the abdomen was so bent as to whip it instantly from the mouth. I craned my neck all the more; I even used my magnifying glass, but the work was done too quickly for the eye to catch the movements.

For an hour while the process of reinforcing continued, the little mother always went out for water through the crack nearest the nest and regularly came back through the same crack. Only once did she enter on her return through another crack a few inches toward the north. Did she go from there to her nest? No, she left immediately by the way she had come; presently her face appeared at the right opening and she proceeded direct to her nest and resumed her work. Place memory was again demonstrated.

When at last she seemed to consider her work done and failed to return, my attention was directed to the behavior of some half dozen other *P. mellipes* in the building, but of this nest and its contents we shall have more to say later.

A second *P. mellipes* was watched for fifteen minutes as she nervously walked on the walls or flew from place to place within the narrow confines of the shack. She was seen to enter a dozen empty cells of mud wasps, and one in particular claimed her attention. An hour's wait, however, revealed no further activity on the part of this prospector.

A third individual was seen to return often to a new and partly wet cell of *S. caementarium* which was in course of construction, and I am sure would have started something had not the owner, returning with her mouthful of mud, routed her with such hearty vigor that *P. mellipes* was discreet and never returned. A fourth *P. mellipes* on an exploring expedition likewise entered several old nests but did not remain in any of them. They generally seem hard to please or for some unexplained reason they do a large amount of prospecting before they finally select a mud hut to remodel, although from my standpoint the offerings of available second-hand domiciles are all about equally good or bad.

A fifth *P. mellipes* had a sixth one close at its heels as they both entered through a crack in the wall. The first one entered an unsealed cell and the other one still followed; after a few seconds, a wrangling was heard within and soon after they appeared fighting at the orifice, the victor threw the rival out, and as she fell toward the ground she expanded her wings and flew out at the door. The other remained within. Before I left an hour later, I inserted a blade of grass in the cell to ascertain if she was still present, whereupon she fled in alarm. Late that afternoon I had opportunity to return, and found her not in, but I did notice that the opening of the old cell had in the meantime been enlarged, and the jaw-marks gave evidence that some of the clay had been bitten away from the periphery. By the next morning, more of the clay around the opening had been cut away, and inserting a stem of grass I sensed that some structural work had been done within. Late that afternoon I paused a moment just before train-time and removed the nest, incomplete as it was, to take home, and was surprised to see that more clay had been taken from about the aperture. Looking within, I could see at the far end a completed and open cell.

Now to return to an examination of the first cell, whose closure I witnessed as recorded above. This mother had taken the unused cell and modified it in accordance with the plan illustrated in the diagram (fig. 39). In cell "A" the inside walls were smooth and slick, and a black spider of the species *Phidippus tripunctatus* [J. H. Emerton] was within. Like many other individuals of this species observed, this wasp had failed to remove all of the legs of its prey, but those which she had taken off were amputated in a workmanlike manner — that is, with a nice straight cut a few millimeters from the base. Again, she differed from others in her work in that the spider's remaining legs were not completely paralyzed. How often we read in the text-books that the wasp stings the prey so that the body remains fresh food for the young, while the legs are paralyzed to protect the young from injury. In this spider the body seemed dead, but the remaining legs were active and clung to my pencil or finger with great tenacity. After the lapse of five days it was in about the same condition of activity as when the nest was first opened and 15 days later this spider shed its skin. This little incident may have a deeper meaning, too. It is possible that this species directs her stings to affect other parts besides the legs, for what would be the utility of stinging so as to paralyze the legs, in a species which has the habit of cutting off the legs of its prey? An egg, now discolored, was sealed to the left lateroventral surface of the abdomen. Cell "B" was likewise smooth on the inside; all of its roughness faced into the empty cell "C" where it would do no harm since it was empty. In "B" one spider, a young *Philodromus* sp. [J. H. Emerton] was found. This was dead, bore a dried, shriveled egg upon its dorsum, and had only three legs. The five that had been removed were the first, third and fourth on the left side and the third and fourth on the right. All these seemed to have been cut at the joint between the coxa and the femur, leaving clean-cut stumps. "D" was a very large cell between the last brood cell and the plug, and contained sufficient space for at least three *P. mellipes* cells, but without taking advantage of this space she had proceeded to plug up the orifice. We ought to pause here to ask how the habit was acquired of sealing up the opening of the tunnel or old cell when her own cells within were sufficiently sealed, since in many situations of her nest, as under bark of trees, etc., she cannot seal up the cavity or space containing her cells.

Fig. 39 again shows the great versatility of this little creature. In this case she did not actually build the usual thimble-shaped cells, but modified her work to resemble that of *Trypoxylon clavatum* (fig. 54), and actually built walls to separate the larvæ instead of following the more elaborate plan of building separate cups for each. In contrast with the precaution of leaving an air space, as seen at "D" in fig. 39, and sealing the opening, we see (fig. 38) where the old mud-dauber's cells were completely filled with thimble-like cells of *P. mellipes* and in other cases some of them were partly exposed to view, not having the plug at the opening. All of this shows that "habit" has not yet bound this creature to her wheel, and it suggests that this species' instinct is today in a very unstable condition and will bear watching for a solution of some of the most perplexing problems of psychic evolution.

The promising prospect of wresting from *P. mellipes* some of the secrets of her nest-building caused me to return to Wickes. But on this second visit, in September, the outhouse that had previously been of interest proved void of *P. mellipes.* At 5:35, however, almost twilight, I found in a dark corner of another shed nearby a *P. mellipes* atop the nest of a mud-dauber. The nest was more or less dilapidated, with whole sides torn out of certain cells. At first this condition aroused little attention, since I thought the nest had merely met with some calamity such as an attack by birds, or disintegration by the elements. Later investigations, however, showed that this destruction was the work of *P. mellipes;* hence I give briefly the condition of the nest when found. One cell that had been sealed empty had the entire top removed; a second upper cell had likewise had the top torn away, but this had been a sealed cell, and the pupal case of the *Sceliphron* was hanging over one wall, where evidently it had been pushed by *P. mellipes* as she was demolishing the cell and carrying the mud inside for her new cells. The two cells underneath were of special interest. One had the wall about the opening removed, forming a rather large circular aperture, twice the size of the original opening. This cell will hereafter be referred to as "X." The mandible-marks were vividly etched about the periphery. The other under cell was the main item of interest, because the *P. mellipes* was at the time building her own cells therein of the mud which she obtained by breaking down and carrying away other parts of the old nest. When she had first begun to make her cells herein, she had evidently gotten her mud from the very same cell, for enough had been removed about the opening to enlarge it to two or three times its normal size and the edge was all scarred with mandible-marks. This cell is known as "H."

P. mellipes was on the nest at the time of its discovery, but left as I approached. After a lapse of nine minutes she returned, flew into cell "X," presently came out and flew into her own cell "H." She went in head first; the abdomen partly protruded and showed every indication that she was at work within the cell. Evidently when she entered cell "X" she removed a mouthful of mud from one of the walls, and within the cell which she had appropriated she was busily fashioning it into her own cells. The next two mouthfuls proved the correctness of this assertion, for she was next actually seen biting out mouthfuls of mud from the broken cell on top and carrying this material into the cell she was reconstructing. Since these pellets were not carried out, it is evident that they went into her masonry. Thus she removed six loads from the wall and took them down into her cell; then she went out and returned in 12 minutes. Throughout the period of observation she often left the nest, undoubtedly for water, and returned each time after an interval of about two minutes. The light was dim in the corner of the shed under the roof where she was at work, and I could not see whether she moistened the dirt first before removing it or wet it as she was actually at work biting it out with her jaws. Of only this much I was certain: that the soil as she carried it in her mouth was wet and glistening, and very close scrutiny revealed that the spot where she got her mouthful of dirt was always dry. *Odynerus geminus* was lavish in the use of water, when mouthful by mouthful she bit away the chimney over her nest, but this economical little creature either bit away every particle that contained water or bit out the dry dirt and disgorged upon it just enough water to make it of the right consistency. She came repeatedly to the wall of the nest apparently empty-handed, made actual mud in her jaws for short periods and then went away. Working thus, she continued to remove the foreign portions of the nest, carry the mud to a certain cell and there to fashion her own dainty little thimble-shaped cells. Often, as she worked, her hind legs extended out to view, and frequently I could see her curl the abdomen under the body, as previously described. Again I tried hard to determine the question which had puzzled me on previous occasions, whether the water oozes out of the tip of the abdomen when it is so inflexed or whether the drops come from the mouth and are whipped into place by the tip of the abdomen as it begins to rub down the mud, but again I was unsuccessful in the dim light.

The speed of her work may be judged from the following sample of her comings and goings, and the number of mouthfuls of mud removed after each trip. She went out at 5:40 p. m., returned at 5:42; out two minutes, then removed 8 mouthfuls of mud and worked it into her own architecture, consuming 6 minutes at the task; out again at 5:48, in at 5:49, absent one minute, removed 7 loads of mud in the same fashion in the following 6 minutes; out for 2 minutes, then transferred 6 loads of mud to her own structure in three minutes; out again for three minutes, and in the following 5 minutes took out 6 loads of dirt.

The wall-structure of this Sceliphron nest had not been reinforced in the usual way; consequently it was thin and quantities of it were required to make the compact cell of *P. mellipes*. Hence the tops of three large cells had been demolished and much additional material taken from the other two cells, to put into the making of the three stocky little cells which had been built within the one chosen mud-dauber's cell.

The *P. mellipes* builder did not each time return direct to one spot to get her mud, but walked all over the nest in a searching attitude, sometimes more than once, before stopping to get her mouthful. Sometimes she went to the same place on two consecutive trips, but more often she landed at a new spot each time. At about 6 o'clock the cup-shaped cell was completed very near to the opening, and the next few loads brought in were used to fill in the niches about the new cell. When she left at 6:08 and did not return at the usual time, I suspected, since her nest seemed completed, that she had gone in search of a spider. I waited until 7 p. m., when it was quite dark in the shed, but she did not return. Occasional visits during the two days following showed me no evidence of the return of the mother. Perhaps she had met with a tragedy; perhaps I had frightened her away by trying to observe the progress of her work by the aid of lighted matches. The cell which she had completed before her disappearance was found to be empty; the middle one contained a spider, *Phidippus* sp. [J. H. Emerton], and had a discolored egg fastened across the dorsal surface of the abdomen. The remaining cell, the oldest of the three, contained an almost full grown *P. mellipes* larva and a few fragments of spiders. It was replaced and on September 24 it spun its cocoon.

In the living-room of the club-house this yellow-legged Pompilid was once seen crossing the floor with her spider. When I came too near she flew to the window, but presently she returned slowly and cautiously. During her absence I examined the spider, a young *Phidippus* [J. H. Emerton] and found that it had only one leg, a front one; the other seven had been bitten off close to the body. Thus it seems that each individual *P. mellipes* trims the legs of her spiders exactly to suit her own fancy, and not in accordance with any law or fixed instinct. She left the spider lying on its back; when she returned she mounted it without changing its position, which made the ventral side of the spider rest against the ventral side of the wasp. Her body, and that of the spider, are about the same size, so she nicely covered it as she trundled it to a point some three feet away. Despite the length of her legs she was unable to lift it from the floor, so it rubbed against the rough boards until I thought surely it would get a splinter in its back. She stopped alongside a loose board and without leaving her spider or changing her position in the slightest degree, she paused and rested for a full half hour. Sometimes, while still in the same position, she would lift her hind legs and stroke her body with them as in toilet-making. The second half hour was dragging wearily on; her capacity for waiting seemed to exceed mine. I blew my breath gently but directly upon her; this immediately aroused the antennæ to very wild movements, but soon her agitation cooled and she quieted them. This, however, did not induce her to move, but she became quite tame, so that I could approach her near enough to see that with her mandibles she held the abdominal tip of the spider as it lay beneath her. Successive blowings at length roused her to move on with it for a distance of two feet, where she lapsed again into the same loitering, sitting astride her spider. I wished to let her alone and observe her natural capacity for loafing, but I could not remain longer so took both wasp and spider.

In the foregoing pages we have remarked upon the unusual versatility of this little wasp. This characteristic is generally regarded as an advantageous faculty, but we must not forget that versatility may lead to stupid, labor-wasting ways as well as ingenious, economical methods. Witness the following story of wasted time and energy.

This *P. mellipes* was seen carrying a spider under her body in the usual way, *i. e.,* venter to venter and the anal tip grasped in the wasp's jaws, while the first pair of legs held it close to the wasp's body. Thus the wasp walked actively about on the face of an almost perpendicular bank, and entered about a dozen abandoned *Anthophora* burrows, coming out very soon from all excepting the last; there she remained for some time. I placed a test-tube over the hole to take her when she should emerge, but when she saw the tube she darted back into the depths of the burrow, but soon again ventured to the orifice. Seeing that something was wrong, she went back into the hole again, got her spider and attempted to escape with it, which I permitted. After that she carried this spider in and out of more than thirty holes, always holding it in the same manner, going into one hole twice without seeming to know it, becoming entangled once in a spider's web, from which she cleared herself with a few well-placed kicks, once tumbling down with her burden from the top of the bank, but spreading her wings when half way down and regaining her position. Eventually, she came out of one of the many holes empty-handed. With a probe I found the hole so shallow that the spider was easily poked out. It was legless; the legs had all been bitten off very near to the body. This is my first record of a totally delegged spider. The victim, a *Pisaurina undata* Htz. [C. H. Shoemaker], was evidently dead. For the next half hour she continued to entertain herself by going into other abandoned holes. It is possible that this particular wasp had a mud cell hidden in one of the bee-burrows and, becoming confused at not finding the right cell, abandoned the prey.

P. mellipes, too, has her enemies. In September, 1919, a cuckoo-bee, *Tetrachrysis pattoni* Aaron [S. A. Rohwer], was reared from one of its cocoons.

A brief summary of the nesting habits of the members of this genus, as far as they have been reported, might be of interest here in a comparative way, although finer details of the methods of manipulation are needed before we can get much from a study of their relationships through this behavior.

The pots of *Agenia punctum** are made of mud and are shaped like oval jars, each smaller than a cherry stone. Those of *A. hyalipennis* affect a conoid form, narrow at the base and wider at the mouth like a primitive drinking cup. The nests of both species are glazed on the inner surface; this makes them waterproof. (Fabre, The Mason Wasp, p. 84, and Sharp, Insects, Pt. 2, pp. 105-106.)

Agenia carbonaria contrives a nest much like a wide-mouth bottle. It appears that this insect has not learned

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*Many of these insects were formerly known under the generic name of *Agenia*, but since the name was preoccupied in the Hemiptera, the genus is now named *Pseudagenia* (Banks, *Journ. N. Y. Ent. Soc.* 19:221, 1911). No attempt is made in these reviews to standardize the nomenclature, but each name is the one used by the author cited.

the secret of kneading its material with saliva, so its pots have not the proper permanency, and for this reason they are not placed in exposed situations. (Step, Marvels of Insect Life, p. 426; Sharp, Insects, Pt. 2, pp. 105-106.)

Pseudagenia adjuncta makes tiny mud cells in the old cocoons left in the nests of *Trypoxylon politum,* and it also plasters larger mud cells to the same nests. (Rau, Journ. Anim. Behav., *6;* 42, fig. 21, 23.)

Agenia subcorticalis builds nests in old *Pelopoeus* cells, taking the dirt from the walls of the nests in which she is building, moistening the dirt with water as she works. (Hartman, Bull. Univ. Texas, 6 : 51.)

Pseudagenia blanda builds stout cells of mud, cylindrical and thick walls, ranged alongside each other, sometimes as many as four cells in a nest; they are placed in the fissure of a vine or at the base of a tree. (Williams, *loc. cit.,* p. 97.)

Pseudagenia makilingi makes a two-celled mud nest which is hidden in a curled-up leaf. (Williams, *loc. cit.,* p. 97.)

Agenia bombycina makes clusters of little mud cells in crevices. (Peckham, Wasps Social and Solitary, p. 244.)

Pseudagenia architecta makes twin cells of mud. (Rau, Wasp Studies Afield, p. 84.) These nests are probably similar to those described by the Peckhams (Wisc. Geol. & Nat. Hist. Surv., *2;* 165-166), but they do not mention any attachment of the cells in pairs. Ashmead (Psyche *7*; 66. 1896) records that the nests are thimble-shaped, and are found under bark, logs and rocks. This brief description by Ashmead is applied also to three other species, *A. bombycina, A. corticalis* and *A. mellipes.*

Agenia variegata. This species is recorded as burrowing in the ground. (Riley, Am. Nat. *8;* 8. 1874.) This, however, needs verification, since no other record shows similar behavior for members of this genus; Bouvier says (Psychic Life of Insects, p. 190) that *A. variegata* closes the entrance of her nest with balls of spider web which she compresses into a tight wad, although he does not state what kind of nest this species makes.

Pseudagenia nyemitawa. This wasp plasters a two- or three-celled nest on trunks or logs. (Williams, *loc. cit.*, p. 98.)

Pseudagenia caerulescens makes a little mud nest within the silken retreat of a jumping spider, the web of which is usually in a crack in a bamboo stump. (Williams, *loc. cit.*, p. 100.)

Pseudagenia sp. had enlarged a burrow in a honeycombed log. Within, a short tunnel was found which contained three cells, each supplied with a spider. (Williams, *loc. cit.*, p. 101.)

Pseudagenia macromeroides shows indications of a semi-social habit; the mud cells are placed in groups in sheltered places. (Williams, *loc. cit.*, p. 102.)

Pseudagenia okowa is a twig-nesting wasp. She partitions the hollows of slender twigs into 2, 3 or 4 cells, and stores them with the delegged spiders. The partitions are of mud, and in addition the outer one is smeared with a gummy substance (Williams, *loc. cit.*, p. 103).

Thus we see that the genus *Pseudagenia,* more often called *Agenia,* although it belongs to a family of wasps that dig burrows, comprises for the most part potter wasps that build neat pots of various shapes according to the species, in various localities, with or without garnishments, according to whether the nest is in the open or in protected situations. All of these species carry mud from afar to build their nests. Sometimes, however, some individuals of *P. mellipes* eliminate this work by building their nests in a daub of dry mud and carrying only the water to this point of operations, thus saving a great amount of the work. Not all individuals of *P. mellipes* behave in this manner; this variation shows at least that this habit is new to the species and probably in an incipient stage of higher development. One must not overlook, too, that Hartman has discovered that *Agenia subcorticalis* uses the cells of *Pelopoeus* merely as cavities in which to build her own small cells of the ancestral type. Thus she may have as many as five of her own cells inside a single chamber of a mud-dauber's nest. Indeed, *A. subcorticalis* too goes a step farther and not only closes each of her individual cells, but builds a plug over the opening to the large chamber, thus offering to her enemies an additional rampart. The dirt is taken from the very nest in which she is building her own; she gnaws off pellets, after having moistened the dirt with water from her gullet.

When one sees the variations in nesting habits within each of these two species, *A. Mellipes* and *A. subcorticalis,* and compares the behavior of the various species within the genus, one cannot help but look toward the day when naturalists will be able to show the graduated series from the nest of most primitive structure to one of great complexity and the relationship between the nesting habits and anatomical characteristics.

CHAPTER III.

The Grass-Carrier Wasp, *Chlorion (Isodontia) auripes* Fern.

The behavior of this very interesting creature was incompletely told in "Wasp Studies Afield," pp. 203-206, and Trans. Acad. Sci. *25;* 199-201, 1926. Since that time I have been able to add, piecemeal, several details of its life history. In 1917 we occasionally encountered the striking spectacle of a wasp flying high with a long blade of grass or strand of excelsior in its jaws. We finally traced these wasps to carpenter-bee burrows in wooden beams, where they were carrying in this material, and so ended our information on the habits of the species. "Thus the season ended without our having ascertained whether they used this material for bedding, for food, or as a plug to close the orifice." With our curiosity thus aroused, we were ever on the watch for their burrows in the wood.

We have previously quoted Packard, who tells how these wasps use analagous material for plugging their nests. More recently we were pleasantly surprised to find a note by F. X. Williams* which has some bearing on the phylogeny of this habit. He records that a slender wasp from Philippine Islands (species not recorded) "of the *Isodontia* group, provided with slim mandibles and legs unfitted for digging, was observed gathering tomentum or wool-like material from the under side of a green leaf, and she evidently makes use of some preexisting hollow as a nesting place, dividing the cells therein with the material gathered."

My first interesting discovery was a pine board in horizontal position, above a doorway in an abandoned

*Philippine Wasp Studies, p. 119, 1919.

cabin near Kirkwood. A typical carpenter-bees's old hole had been filled in with grass, tightly packed. The diameter of the hole at the opening was 7/16 inch (see 1 in fig. 41). This opening led to a gallery going east for a few inches (see 2 in fig. 41), then turned back sharply and went toward the west (just below 3) for 8 inches. A third gallery which ran parallel with gallery 3 turned off at a point near figure 2. This third gallery is indicated as 5 in the figure, and 6 is its opposite wall. The excavation had originally been made by a carpenter-bee, and various insects had since occupied the quarters whenever an opportunity occurred.

Seven large, dead carpenter-bees were entombed in that portion of the tunnel marked 7; these were crowded close together in a space of three inches, and sealed up with a wall of mud; this wall was at "X," just to the left of 3. These bees had evidently died during the winter, and instead of sweeping them out as debris, the next tenant, the *Monobia* mud-wasp, had merely swept them into the far end and sealed them up. The remainder of this tunnel (below 3) had evidently been used by the wasp *Monobia quadridens,* for there were mud partitions to the left and to the right of chamber 9. The only evidence, however, of its having been occupied by those wasps was the mud partitions, and the hole in one of them made by the new *Monobia* wasp in emerging. This gallery, however, now that these wasps were gone, had been used by other insects which had made their way to the opening at 1 and thence through the holes in the partitions. The region designated as 8 had been used by a bee whose cocoons are identical with those of *Osmia cordata.* The *O. cordata* that I know, however, build their nests in abandoned mud-dauber cells, which they partition into rooms and re-seal, using a waxy substance for both partitions and plugs. The cocoons which were found in this cavity in the timber were in mud cells just large enough to hold them, and showed every evidence of having been made by this species. This portion of the tunnel must have been used for more than one generation of bees, for at the far end some debris, including old cocoons, had been swept back. The portion of this tunnel indicated by 9 in the figure contained an old Lepidopterous cocoon and bits of the old pupal case. The caterpillar had evidently sought shelter in the hole in the board, and pupated there. The tunnel at 2 had a mud partition about 2 inches from the turn in the gallery; this marked off one cell 1 inch long which was empty, although it may have contained a larva that fell out when the board was broken and pulled out of the cabin doorway.

I have mentioned in a previous publication that it seems that *Monobia* does not spin cocoons. In this nest too I found unclad larvæ (fig. 42) but I also noticed that certain portions of the wall were veneered with a substance that had hardened into papery material, white and very thin. This may have been substance from the intestinal tract eliminated just before pupation, for it was not distributed with any degree of regularity. In one cell the entire mass was spread on the partition, with the overflow covering a portion of the floor.

The portion of the tunnel indicated by 5, and its opposite wall by 6, had been burrowed by the carpenter-bee and showed unmistakable signs (the remains of mud partitions) of having been used later by the *Monobia* mud wasp. This gallery was clean and empty except that at its extreme end was a cocoon of a cuckoo-bee. The last wasp to fall heir to this much-used nest had been *Chlorion auripes*, for the entire gallery from 1 to

4 was packed with grass;* some of this was dried and faded, other strands still green like well-cured hay. At 4, at the turn of the gallery, was a tightly packed plug made of this same material. (For details of this portion see fig. 43.) The inner portion of the plug, *i. e.*, the end facing the nestling, was of material (see arrow in fig. 43) which was noticeably finer in its texture than the outer strands; in fact, it appeared that the first material carried in must have gone through a process of malaxation; the outer strands were coarse and loosely placed, as is clearly shown in "X" in fig. 43.

After making the cell so clean and tidy, this mother had evidently deposited her egg on an Orthopterous insect, but despite her precautions a cuckoo-bee had outwitted her. Let us place it to her credit, however, that all evidence indicated that the parasite had not entered after the work had been completed, but, sneak-thief fashion, had entered during the early process of stuffing in the grass while the *C. auripes* was away for material.

In January, 1919, I found among a lot of sumac stems gathered at the southwestern edge of this city, three old stalks (fig. 44) which gave evidence of having once harbored the young of this species. The hollow space in these had a diameter of about ½ inch. They were all closed with the characteristic grass plugs, and in two cases (A and B) there were brown cocoons pushed close together, 2 in one and 4 in the other, with grass plugs beneath and above the cocoons, which served as a floor and roof, and separated this portion from the rest of the long stem. These cocoons were nearly ¾ inch long, and the grass plugs at each end of the cell which they occupied were each about an inch in length. In another stem (C) the unbroken pith at the bottom of the cavity

*In the figure the grass has been removed from the oriface at 1.

served as a floor and no grass was needed. Three inches above this pith floor was a plug of grass, an inch long and tightly packed as usual. No pupa of the grass-carrying wasp was found, but at the bottom of the chamber were four pupæ of Diptera.

I have not been able until now to find just what this creature preys upon. Other members of this genus gather Orthoptera for their young; and my suspicions in this matter were confirmed when I found in one of the sumac stems, along with particles of grass, a half-dozen wings of a tree-cricket. These were submitted for identification to Mr. A. N. Caudell, who writes: "The wings are those of some species of the gryllid genus *Oecanthus*. All appear to be of the same species. *O. quadripunctatus* Beutenm. is a very common form, and these wings show no detail at variance with those of that species."

The next season, after prolonged searching, I finally caught the wasp red-handed with Orthoptera of three distinct species, and learned some details of her method of handling them. It was in early September, 1919, that one was seen carrying a green cricket to her nest. She carried it easily under her abdomen, and was trying to gain entrance to her burrow in the wooden porch. My presence frightened her, and she flew to a bush nearby and disappeared among the foliage. Some ten minutes later I saw her come out, still clinging to her cricket; then she was captured, robbed of her cricket and liberated. A half-hour later she reappeared with a second one of the same species. To all appearances the cricket was dead, but when examined two days later it was found to have emitted large quantities of excrement, and with a magnifying glass I could see a movement of the palpi. No other part of the body responded perceptibly to a stimulus. Later in the day I opened the nest and found sixteen more crickets belonging to two species; there were fifteen *Oecanthus latipennis* Riley [A. N. Caudell], (fig. 45), twelve females and three males, and one lone male of *Conocephalus memorale* Scud. [A. N. Caudell]. The following evening, nine of these were still alive, as was indicated by slight movements of the palpi and ovipositors, and pulsation of abdomens, and an occasional twitch, in response to stimulation, of a leg or an antenna. On their third day it was apparent that their remnant of vitality was waning. Two more died five days after their capture, one at eight days, and the remaining six at eleven days after they had been caught and stored by the wasps. This shows conclusively that *Isodontia auripes* does not kill her prey outright, but that the captives retain life in a paralyzed state for several days after they have been imprisoned.

Two specimens of a third species of Orthoptera, *Orchelimum vulgare* Har. [A. N. Caudell], were taken from a mother wasp while she was bringing them to her nest. These, too, were paralyzed, and lived in my tin box for four days, occasionally responding to stimulus by movement of the antennæ or wings.

The prey of this wasp so far represents three genera, *Oecanthus* or tree-crickets, *Orchelimum* or meadow grasshoppers, and *Conocephalus* or the smaller meadow grasshoppers.

These wasps are not exempt from the ravages of parasites; a cuckoo-bee emerged from one cell, and its pupæ were found in others. While one wasp mother was bringing in and storing provisions in her nest, a silver-winged fly, *Argyromoeba tigrina,* was hovering at intervals about the burrow. At no other place were these silver-winged flies noticeable at this time; they confined their attention and movements to the spot directly in front of the burrow in the wood, although none was actually seen to enter the hole.

These wasps have learned to use sites other than carpenter-bee burrows in wood. In a clay bank at Chesterfield, Mo., on July 3, 1921, I found where two of them had used the old burrows of *Entechnia taurea.* In the clay bank at Wickes also a burrow of *A. abrupta* was found containing the characteristic nest and grass stuffing of this wasp.

The life history of this creature is not half told, and the road to the discovery of more details is beset with many difficulties. Even if, after weeks of watching, one does find a nest, one soon grows tired of only seeing the wasp enter and leave; all of her wonderful work is done in the dark and behind closed doors. Furthermore, the attitude of this owner of the burrow toward our prowling and meddling about her home is not in the least friendly, while the attitude of that larger owner of the premises involved is often precisely the same, in an intensified degree, and frequently expressed in as stinging a reproof as the other. To be sure, one can await the absence of proprietors, both large and small, and with an ax deface some stranger's house or shed and thus add something to the biology of the creature, but the opening up of the nest can at best add but little to the solving of the problems of behavior—the exhibitions of habit, instinct, intelligence, etc., which one can often observe in creatures that work in the open.

CHAPTER IV.

An Assortment of Twig-Dwelling Wasps.

The Aphid-Huntress, *Diphlebus biparitor* Fox (S. A. Rohwer).

This wasp (fig. 46) is highly interesting because it is, so far as I know, unique in its manner of nest-building. Twig-inhabiting wasps generally excavate a tunnel in the pith, or find one already excavated, then build partitions across this hollow, dividing it into rooms, and fill each with food and deposit an egg. Thus these cells are completed one atop the other. This wasp, however, digs out a narrow tunnel down one side of the pith of a fairly wide stalk, or digs one which fluctuates from side to side in the pith chamber, and then adds pockets branching off to the side of this, in which the nest provisions and egg are placed. This necessarily means that thick stems must be used, for in narrow twigs this type of nest would be impossible. A more complete idea of the nest of this species will be gained from the description of three or four which I studied in detail. Individual variations are always of great interest and value, but I have not yet observed a sufficient number of these nests to know which is the standard form for the species and which the individual digression in certain details, so I shall record them here in the hope of learning more later.

The first nest discovered was in the pith of a large sumac twig. The tunnel was about 3/16 inch in diameter. Careful cutting revealed the fact that this burrow went down one side through the soft pith very near to the wall, and there were several little pockets branching off from this at intervals, extending across this substance to the opposite wall and downward (fig. 47). The material forming the partitions was the finely chewed pith packed rather loosely, and unused portions of the channel were in places filled with this same material, as though it had been carelessly kicked or dropped there. Undoubtedly the material when bitten out of the main channel is carried out and dropped to the ground. In making the side pockets, the pith is probably more carelessly tossed about. Many wasps mix this pulverized pith with saliva to make strong, compact partitions, but here it is so loosely placed that a puff of wind blows it away.

The main channel was 10½ inches from the top aperture to the bottom. This, plus the seven lateral cells, must have made a heavy task of excavating for so tiny a creature. The lowermost end of the main channel (a) was used for a cell; it was ⅛ x ⅝ inch, but had been sealed empty. The partition at its top was ¼ inch thick, and immediately on top of this was (b) a cell of dead and dried plant lice but no egg. Above this the passages from the point "c" to "d" and the neck above the lowermost side pocket (e) were filled with pith which was so loose that it seemed to have been merely thrown in or kicked down. Three of the lateral cells, "f," "g" and "h," each gave forth an adult wasp, while the other three cells (x) as well as the remainder of the main channel above "d" to the point "i" were filled with the loose, soft pith. The remaining upper portion of the tunnel was empty.

The next twig home of *D. biparitor* was so similar to the one just described that the explanation of the figure seems quite sufficient. There were five cells, two of which were made out of the lower extremity of the main channel. From this nest I learned that the young wasps make no cocoons, and that they arrive at maturity and emerge in inverse order of the deposition of the eggs, *i. e.,* the uppermost matures and emerges first. They emerged from May 1 to 10.

Another nest was a fortunate discovery in that it gave accurate data on the period of development of the young wasp. The nest was discovered on May 28, just when the mother was finishing the provisioning and ovipositing. It is noticeable that this mother was completing her nest 3 or 4 weeks after the wasps emerged from the nest described above. This may mean that a second generation was being produced in the season, but we must not be too hasty in so concluding without considering that the two records were made in different years, and the weather and temperature may have influenced their emergence. When the wall was removed from one side of the twig, the cells were all found to be packed with wingless aphids, *Schizoneura,* probably *lanigera* [J. J. Davis]. One of the cells contained twenty-five aphids, by actual count. The egg in this cell was cemented to one of these, and was about two hours old. This afforded us an excellent opportunity to watch the development through the period of growth. This egg hatched in thirty hours. After five days of its feeding upon the aphids, the stock was exhausted and the waspling lay quietly at the bottom of the cell preparatory to pupating. Two days later a slight constriction appeared in the middle of the upper half of the body. After three days more (June 9) it was a completely formed pupa, but without a cocoon. Five more days were required to complete the pigmentation, and the final three days were spent in spreading the wings, straightening the legs, and in generally expanding the body. While I was examining it on June 17, it sedately walked out of the stem, a handsome adult female. Thus the life cycle from egg to adult for this insect was twenty-one days.

Another twig was examined which was taken at Tower Grove Park on April 27. When the twig was cut open, an adult popped out; it was replaced in the cell and strips of mica were sealed over it. The twig had a 6½-inch tunnel and 7 cells. The upper 3 inches of the channel were vacant, 2 of the cells were empty and the remaining 5 were occupied by black adults. From here they did not emerge until May 2; then they worked their way out of the cells by kicking the filler back of them, the upper ones emerging first, and the last following them on May 5.

One other elder stem was found on July 4, 1918, to contain an adult wasp, *D. biparitor;* this was in all probability a new one just emerging. When the twig was split, three others were found which had the wings spread and were all ready to come out. The twig was a large one, as usual, one-half inch or more in diameter, and the tunnel, which was barely one-eighth inch in diameter, oscillated to the full extent of the pith-chamber, and sent off ramifications or side pockets which served as cells. The terminal cell, at a depth of eight inches, contained an almost full grown cuckoo-bee and some remains of plant-lice. The second and third, seventh and eighth cells were all filled with plant-lice, in a mummified condition; evidently no egg had been laid with them, or if deposited it had not hatched to consume them. These cells contained each 25, 26, 22 and 25 aphids, respectively, all of the apterous form of *Rhopalosiphum rhois* [J. J. Davis]. This is not the first *Diphlebus* mother which exhibited such astonishing precision in "counting out" about 25 aphids to each cell.

Surely she can have no comprehension of a number so large, but she must have a keen sense of quantity. It would not be surprising if a wasp mother could perceive the difference between three and four fat caterpillars, but it is surprising that she can measure out, either by number or quantity, equal portions of articles so small. The first, fourth, fifth and sixth cells gave us simultaneously an adult each on July 4, while the ninth and tenth cells each harbored a full grown larva when the nest was despoiled at that date.

Another Aphid Huntress, *Diphlebus tenax* Fox [S. A. Rohwer].

It is interesting to see to what degree this species is similar in its nesting habits to its sister species, *D. bipari-tor.* An uprooted tree with much soil clinging to the roots afforded the nesting-site for one of these little wasps. In the firm earth which still clung to the roots and in the area of bare earth exposed beneath, a number of Hymenoptera were or had been nesting. The burrows of *Trypoxylon sp.* and the turrets of the white-banded bee, *Entechnia taurea,* were there. Several kinds of bees had already taken up their abode among the dried roots, although it was at once evident that the place had not been available for their use for more than a season or two at most. This is a correct indicator of the readiness, even the eagerness, of solitary Hymenoptera to utilize any bald, sunny area where the vegetation will not impede their work.

Besides these terrestrial dwellings there was in this instance an attractive nest of a kind new to me, in the very wood of the exposed roots. In a portion of the root two feet from the ground but well sheltered by a lump of soil above, was a small crack. Beneath this was a neat heap of sawdust. A little black wasp was seen to leave the hole and return at ten-minute intervals. The prey which she carried could not be recognized, but when later the burrow was opened, aphids of the species *Macrosiphum sp.* [J. J. Davis] were found. One cell contained 32 aphids, another 25, and a third one 11 aphids and a half-grown larva. The burrows in the wood were a little over ½ inch long and ⅛ inch wide, and they were plugged with finely-chewed wood. Whether this wasp had the power to do her own tunneling in the hard wood, or whether some beetle or other insect had done the excavating and she had merely scraped the shavings for plugs, I do not know, but from the unique type and condition of the burrow I can only surmise that the work had been done by this little aphid-hunter.

A second wasp of the same species was seen nearby, which indicates that this must have been a good place, although the unique character of this nesting site throws little light upon the nature of the usual place of nidification.

Another was subsequently discovered in February, in a cut catalpa twig in a St. Louis park, and in May one was found in the dead twig of a rose-bush in the dooryard. The mother was in the vestibule of this one, and remained in it while the twig lay on my table for twenty-four hours; although the twig was opened, the faithful mother was loath to leave. The channel was about 1/16 inch wide, 4 inches deep; each of the five chambers was ½ inch in length, and the partitions were of pith. The two uppermost cells contained immature aphids, *Macrosiphum sp.* [J. J. Davis], and the lower cells brown ones of the same species. There were approximately thirty-five or forty in each cell. The cells were situated one below the other, excepting the lower two, where the pith chamber was wide enough to harbor them two abreast.

THE DEBRIS-CARRYING WASP, *Silaon niger* Roh. [S. A. Rohwer].

After opening a number of *Silaon niger* nests in sumac twigs, I soon became so familiar with their characteristics that I could easily recognize them at sight. After they had grown to seem such common and familiar objects, it was indeed a shock when I discovered that the previous records in the literature contain nothing about this quaint little home built of rubbish or even the fact that *S. niger* (fig. 48) nests in twigs.

For a long time, in lieu of a familiar name I called it the debris-carrying wasp. It nests in hollow twigs, but the evidence indicates that it uses old burrows left by other insects, and so probably does not do any excavating of its own. Some of the nests have contained relics of the former occupants packed in the bottom of the burrow (see pith chips left by *Hypocrabro stirpicolus* at [x] in fig. 49); others had at the aperture at the top traces of the mud seal of the former Eumenid, and one showed that a *Ceratina* bee had formerly nested there.

S. niger does not make either partitions or cells in this burrow, but merely fills up the tunnel from bottom to top with bits of any material that she finds convenient, with her eggs and provisions scattered along at intervals in the mass. It is an unsolved mystery how the tender larva can survive unprotected in this heterogenous mixture, or how it can find all of its food. I have never been so fortunate as to find a nest with the young in the early stages of development, and from its table it leaves not a crumb, that one might know what its food was. Figure 49 shows three firm little clay-colored cocoons in the loose mass of debris. For the filling the mother wasp utilizes whatever material is convenient. The first few nests that I found happened to be near the railroad track, and the builder had picked up small cinders and filled her nest with them—rather an unusual expression of mother love, to pack her tender babe's cradle with nice soft cinders! If these had been the only nests found, I might have said, like the blind man seeing the elephant, "They fill their nests with cinders." But soon I was wondering just what they did before the advent of railroads and cinders in this region, and presently I found an explanation; other nests were filled with other materials, tiny clods, some of which had been put in hard and dry, and some moist enough that they had stuck together, loose dirt, bits of bark, splinters of wood, fragments of leaf or stem, seeds, grass-heads, tiny pellets of insect excreta, disc-florets of composites, etc. Two or three burrows were neatly closed at the top with several wild-oat seeds stuffed in side by side with awns protruding.

Upon opening the cocoons of this species early in July I always found adults therein fully formed; hence I always wondered if the insects were ready to emerge when I broke into the cocoons or whether they would remain in their fully formed condition until some later date, or even until the following spring. An elder twig taken at Meramec Highlands on July 6 showed that the wasps do emerge about this time, for between July 12 and 22, five adults left their cocoons by biting out a little disc at one end. Several others which emerged from their twigs in the laboratory appeared between May 28 and June 20, but their development may have been accelerated by their stay in the house during the cold months.

Several nests from various localities and different years showed so much similarity, in all points excepting the diversified filling, that detailed descriptions of the individual nests seem superfluous. The nests were found in old hollows in the pith-chamber of elder, sumac and horseweed.

The parasites *Cleptes sp.* [S. A. Rohwer], *Ellampus sp.* [S. A. Rohwer] and *Chrysis sp.* emerged from the nests of *S. niger.*

Silaon sp. [S. A. Rohwer].—The little builder of this nest could not be definitely identified by the one male specimen available; the habits are evidently so similar to those of *S. niger* that I entertain a strong suspicion that this may be the same, but while doubt remains I shall list it separately.

The nest was in a sumac stem taken at Wickes on June 28, 1918. The tunnel curved at the top enough to hold in place a plug, ¼ inch deep, of strange construction; it was a motley mass, some bits of soil, grasshopper's dung, a dead Chrysomelid beetle, the shedding-skin of a small spider, bits of dried leaves and stems and various other indistinguishable ingredients. For ¾ inch below this the tunnel was hollow; then came another mass of the same detritus 1¼ inches long, and including five cocoons of a dirt-gray color and 5 mm. in length. They were not spaced with any system, nor was there any evidence that the packing material had been arranged to form partitions, but the entire mass was a jumble. Below this, the channel was packed for 3 inches with roughly bitten pith; this had evidently been left by *Hypocrabro stirpicolus,* for it was interspersed with the remains of flies.

All this would indicate that this helpless little mother cannot bite out her own tunnel, cannot make her partitions out of pith and saliva, and, unlike the Eumenids, cannot carry water or mud to do the work of a mason, but, being deficient in all the talents that make for good workmanship, she picks up what she can and makes the best of it. Furthermore, she probably succeeds, in so far as the prosperity of the species is concerned, for the young in the cocoons seemed to be healthy and unusually free from parasites.

A second nest was found near by, which was just the same in measurements and structure; the only difference was that in the pack of debris 1¼ inches long there were three cocoons instead of five. It was clear that this twig also had been previously inhabited, for the bottom 4 inches was filled with coarse pith mixed with particles of broken cocoons and the inedible parts of flies. Just while I was examining the stem on the morning of July 4, one broke its cocoon and crept out. This first-born was a male.

TWIG WASP, *Solenius interruptus* Lep. [S. A. Rohwer].

In the cut stem of a low catalpa in the Tower Grove Park a nest of *Solenius interruptus* was found on February 13, 1920. The cocoons appeared like those of a Hypocrabro, but the plan of the nest was just like that of *Diphlebus biparitor*, described elsewhere in these pages. A tunnel was dug down one side of the pith chamber; two cells were made in the bottom of this by inserting partitions of pith across it, and above that point lateral tunnels or pockets branched off which served as cells. The main gallery here was filled with pith chips. On May 18, one adult of *S. interruptus* emerged, proving the ownership of this nest.

APHID WASP, *Stigmus fraternus* sub-species *raui* [S. A. Rohwer].*

The twig harboring this little insect was taken at Shaw's Garden, February 2, 1920. At this time it contained larvae in the quiet stage, more properly called prepupae; these were naked, i. e., entirely without cocoons. The channel in the twig was 8½ inches deep, but all of the insects that emerged came from the eight cells in the lower 2½ inches of this. The same type of cells were present above this portion, but of these I shall write later. The cells were just a trifle more than 1/16 inch in width, and their length varied from 3/16 to ¼ inch. The partitions were made of fine pith, and their thickness varied from a little less to a little more than 1/16 inch.

About the 10th of April, two males emerged, but were dead on the floor of the jar when discovered. The eight others, which emerged subsequently, were all females, and came from the eight lower cells in the group mentioned above, in the lower part of the long tunnel. In these eight females we see simultaneous development, at least at that date; all were perfectly and completely developed, and when the twig was split open they briskly walked out, apparently with equal readiness. There were no cocoons, and they all developed with the head up. I was sorry that I had not, at an earlier stage in their development, substituted a transparent wall in one side of the nest, so that I could see how they solved the problem of the order of emergence, i. e., whether each waits for the one above to clear the way before it attempts to break down the roof, or whether the lowermost matures first and struggles over all the others above it.

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*New sub-species described in *Proc. Ent. Soc. Washington,* 25; 100, 1923.

It was mentioned above that the lowermost 2½ inches of the tunnel contained eight cells which gave forth eight perfect females. Above this series were eleven more cells of about the same size, with partitions of the same material and thickness. The masses of dried and mouldy material in these cells were placed under the microscope, and found to be the following, numbering the cells from the bottom upward:

No. 9—A few dried aphids.

No. 10—Dead larvae.

No. 11—Dried aphids.

No. 12—Empty cell from which one of the males had emerged.

No. 13—Two aphids.

No. 14—Three aphids.

No. 15—Eleven small aphids.

No. 16—Sixteen small aphids.

No. 17—Empty cell whence the other male had emerged.

No. 18—Twenty aphids.

No. 19—Twenty-three aphids.

On top of the nineteenth cell was a sawdust plug of fine material, ¼-inch thick. The remaining inch of space above this had been used by some other Hymenopteron that had emerged probably late in the summer, while the inmates below were destined to gladden the earth the following spring.

This series is of high interest since the females, eight in number, emerged from the bottom of the tunnel, while the two males from the top were at a much earlier date. It is also of interest because there was no mortality in the lower cells, the first constructed, while nine of the eleven in the upper portion gave forth no life. Whether this may have been due to the forgetfulness of the mother in failing to oviposit, I do not know; among the fungus-grown prey we did not find eggs or young, but these might have been obliterated by the growth. Another item of interest is the fact that going upward we find the number of aphids in each cell increases; but this might have been due to nothing more than accident.

Another family group of this sub-species was found in a sassafras twig in St. Louis in the winter of 1919-20. The hollow in the twig was quite narrow, and although it contained three insects, there were no cocoons, partitions nor debris to indicate what their past history had been. One adult emerged on April 15, and the other two were mature, black and almost ready to emerge on that date when the twig was split open.

The Fly-Catcher, *Hypocrabro stirpicolus* Pack [S. A. Rohwer].

In a thirteen-inch elder stem taken at St. Louis in February, 1919, were several cells of *H. stirpicolus.* They were distributed along eight inches of the tunnel, and the top four and one-half inches was hollow and empty. The stem was opened, covered with strips of mica, placed in a milk bottle in an upright position, as it had been in nature.

On March 18, one adult emerged from a cocoon. It was not from the top cocoon, as one might expect, but the bottom one. The wasp worked its way upward, and at the end of the second day had progressed about one inch, kicking the loose pith behind it in the crowded quarters. The third day it must have spent in resting, for at the end of this day it had advanced only ¼ inch. It was not observed for two days, but at the end of that period it was evident that it had traversed 5¼ inches; the little insect must have worked hard indeed. This effort exhausted her, however, for at the end of the seventh day she was still in this position.

At this juncture a second wasp was discovered just beneath the first, which had evidently been waiting for her to go on to break the way. She had previously escaped my notice, having been buried in the crumbled pith. The first one had passed a cocoon three inches up; this was intact, but bore small incisions, which had probably been made by the pioneer. The fully developed pupa therein was dead, but its dried-up condition gave every evidence that it had died at a much earlier date, and that the elder brother had not been responsible for its death. The cocoon next above this one was in the same condition. The original position of the second emerging adult was not ascertained; its empty cocoon could not be found; it had been broken by the young wasps which were demolishing everything in their way in trying to force an exit. On March 28, close examination showed that both these young wasps were dead; neither had moved since the last examination, ten days previously. The tight plug evidently had been too much for them to puncture, or perhaps the extreme efforts made by the pioneers when such a large amount of packing was moved was the cause of their exhaustion.

Another stem occupied by *H. stirpicolus* was taken in Tower Grove Park on March 25, 1919. On April 17, the fifth one from the bottom was out of its cocoon and kicking about in the crumbled pith; it must have turned itself about thus, for it was facing downward. During the next two days all seemed to come suddenly to maturity, so that on April 19, three of them were already out of the gallery and resting on the outside of the stem enjoying the full light of their new day, and three others were in the open upper part of the gallery; but since the broken pith was then all below them, they were really free, having no barriers between them and freedom. In the drift of loose pith, more than an inch deep beneath them, one still remained hidden from view, but working its way upward. In the four inches below this were five adults, four of which were working at the pith, and one with the wings not yet spread. Two of the five were facing downward, one of which was diligently attacking the pith and making a good progress toward the bottom. Of course in this case the bottom was open so it could eventually gain its freedom. In nature, however, this traveling downward would certainly lead to its death-trap. Precautions were made to see that none of the twigs were so placed as to put the cocoons upside down, and this must have been an individual variation. This, of course, goes against Fabre's idea of the effect of gravity upon emergence.

The evidence from this nest indicates that emergence in this species does not occur in order of primogeniture, nor in the inverse order, but that emergence does probably occur simultaneously; twelve out of the thirteen cocoons gave forth their young within two days.

A third sumac twig containing *Hypocrabro* was found on April 1, 1920. The stem was cut off too short, but the portion brought home began at the bottom with a plug one-half inch in thickness. Above this the next ⅞ inch contained three cocoons; the partitions between these were so thin that they had been knocked down by the feeding larvae. Next came a partition which was 3/16 inch thick and one more cell, the last, which was ⅜ inch in length and contained a larva. The seven-inch tunnel above this had some interesting features. For 2¼ inches it was filled with packing; in the lower ¾ inch of this, the packing was of the finely bitten and closely packed type, and for 2 inches above that it was the coarse, rough-hewn kind, loosely packed. The gallery for a short distance above this was the mine from which the material had come; the walls there had been scraped clean of the pith, clear down to the wood. Above this the mine suddenly narrowed into the normal passage a little more than 1/16 inch wide. In fact, all the way down the sides of this long fill, the pith on the walls had been all dug out. Apparently the insect works at the mining operation from the bottom upward; when she has need of a plug over the top cell she pulverizes and compresses this material into a plug of desired thickness, about ¾ inch, and above this she tears the pith from the walls in coarse bits as she works upward and drops the stuff below. In this case she finally ceased when she had made this coarse portion of the plug 2 inches deep, but left the mine unfilled. Had she been guided by blind instinct only, she would have continued this work to the end, tearing down above and packing below, until she reached the top. Instead of that, this wasp went part way up the narrow passageway and resumed biting the pith from the walls and packing the large pieces into a partition and continued until she had a plug ¼-inch thick and a comparable mine just above it. The small remainder of the passage was open.

Other communities of *H. stirpicolus* which emerged from elder stems displayed other variations in their method of handling pith for plugs and for filling in the top. Some of the material was coarse, some fine, though the condition seemed usually to meet the need. Sometimes the top of the channel was filled and sometimes left open. It seems there was no hard and fast rule to be followed, but individual temperament and the needs of the site were the deciding factors. One newly filled cell was found at the bottom of a 10-inch tunnel in a stem. The cell itself was ½ inch deep, and covered with a fine partition ⅛ inch thick; six inches above this was another partition just like the first; otherwise the channel was empty. The purpose of this additional partition remains a mystery; it may have been only a temporary structure put in to give added protection to the first cell until the time when the mother was ready to build additional cells. This cell contained prey, twelve fresh dead flies; five were of the species *Agromyza virens* Loew. [C. T. Greene], four of *Phorbia fusciceps* Zett. [C. T. Greene] and three *Agromyza burgessi* Malloch [C. T. Greene]. A very small larva was imbiling from one of the *Phorbia* flies.

The observation of many nests like those described above seems to fully justify the conclusion that these wasps make an interesting distinction between partitions and the fillings for the large unused galleries above the top cell. The same pithy material, bitten out of the walls of the channel, is used for both, but for the use as plugs and partitions it is chewed up fine and made very compact, while for the purpose of filling it is just bitten out in coarse chips, and loosely dropped into place. Figure 50 shows the two kinds of material.

Of nine twigs taken during the winter of 1919-20, I found the number of cells for each twig to vary from 4 to 9. To be exact:

No. of Twigs	Cells
1	4
3	5
2	6
1	7
2	9

The size of the cells within each twig varied considerably; no one mother made all of the cells in her nest the same size; two of these mothers had two sizes of cells, five of them had three sizes, and two had cells of five different sizes. They varied from $\frac{1}{4}$ to $\frac{7}{8}$ inch. The thickness of the partitions varied from $\frac{1}{8}$ to 15/16 inch, and the heavy plugs above the top cell in seven nests measured 3/16, $\frac{3}{8}$, $\frac{1}{2}$, 1, $1\frac{1}{8}$, $2\frac{3}{4}$ and $2\frac{3}{4}$ inches, while the vestibules were from 1 to 7 inches long.

This wasp uses a large number of flies. One cell contained twenty-seven, by actual count; another with a half-grown larva still had seventeen. The great majority were *Agromyza parvicornis* Loew. [J. M. Aldrich]; a very few were the yellow *Chiromeyia sp.* One larva pupated June 19 and emerged as adult on July 4.

The emergence of the young adults from their tiers of cells was watched whenever the opportunity was discovered. On April 1, one struggled upward and out of its twig. This was the top one in the stem, and from the last egg deposited. No others appeared until April 29, when the next one emerged. From that date on to May 11, six others arrived at their maturity and emerged in direct order of the sequence of the cells, from the uppermost downward, and in the inverse order of the deposition of the eggs. On the first of May another nest was observed which, up to that time, had given forth no adults because all were dead excepting the occupants of the two lower cells. At this date one of these struggled upward through the entire mass of filling material and plugs and worked its way out to freedom; the other was not so successful, but was found dead where it had traversed only part of the journey. Nevertheless, these did better than did their sisters of the species *Odynerus conformis* which perforated their own partitions only and then died in defeat, unable or unwilling to make an additional effort to gain their freedom.

These records indicate that in some cases all the adults in a twig emerged simultaneously, and in other cases the emergence occurred in inverse order to the deposition of the eggs. Obviously, data from more material must be gathered before any definite conclusions can be reached regarding the fine details of the way *H. stirpicolus* leaves the nest.*

The dates of emergence which came under my notice extended from April 1 to May 10, with the great majority of young adults appearing near the first of May.

*For more details see our "Wasp Studies Afield," pp. 90-94, 1918, and Trans. Acad. Sci., St. Louis, *24:* 20-21, 1922.

CHAPTER V.

Wasps of the Genus Odynerus and Their Nesting Habits.

Odynerus (Stenodynerus) conformis Sauss.
[S. A. Rohwer].

One might logically expect to find, in the emergence of twig dwellers, that the first egg deposited would be the first to give forth its mature adult. Of all the possible orders of emergence, we find three kinds actually occurring in various species.

1. The first egg deposited is the first to mature, and the insect quietly stays in its cell at the bottom of the tunnel and waits for the others to become adult and clear the way to give it free egress.

2. The insect from the first egg deposited is the first to emerge from the pupal case, and the new adult does not wait for the younger ones above to go before, but breaks into the successive cells and through the numerous partitions, kicking back behind it both debris and brothers alike in its rush for freedom. This pioneer of course clears the way and makes emergence quite easy for the followers.

3. A more specialized order of development is that in which the larva nearest the opening is the first to arrive at maturity and emerge, the one below following it, and so on, so that each has only to break through the one roof over its own cell—provided, of course, that the emergence of the brothers above has been successful.

When one thinks of the order of development of the young of *Ceratina,** where the oldest egg deposited pro-

*An account of the life history of *Ceratina calcarata* is to be published soon in Annals Ent. Soc. America.

duces the first adult, and so the family follows in order of actual age, and the pioneer down at the bottom of the tunnel works up through the mass of partitions, packing and relatives, to freedom, one sees the logic of this procedure and marvels at the fact of its possibility without injury to the tenants above, which we must remember, are without the protection of a cocoon. For something which seems astonishing or illogical in the emergence of twig dwellers, one has only to look at *Odynerus conformis,* where the period of development of young in the same brood is so altered that the last egg deposited is the first to arrive at maturity and emerge, while the first egg deposited develops more slowly and this adult comes out last. It is at once apparent that the advantage of this latter arrangement is that the last insects will come out in good condition without exhausting themselves by breaking through more than their just allotment of partitions, or dying while waiting for their numerous bunkies above to clear the way. It is difficult to guess what can reverse or even make parallel the order of their development. The eggs are deposited in the cells at intervals, perhaps a day or two apart. They hatch into larvae, likewise, a day or two apart; in this quiet larval or prepupal stage they spend the winter, and when the time comes for transformation into pupae, one would expect the changes to occur a day or two apart in the same sequence, or if it did not occur in this way the most one could hope for would be simultaneous changes; that is, since all in one nest have been subjected to the same conditions of climate, temperature, and presumably of food, all would begin simultaneously to constrict about the neck, to acquire legs, wing-pads and antennae simultaneously, the eyes would become pigmented at the same time, etc. But our logic and expectations suffer a shock. We must excuse *O. conformis,* but logic seems to have been omitted from her course of training, which has been entirely practical. There must surely be something inherent in the organism to give rise to the exact opposite from the normal sequence, since surely nothing in the temperature or environment, which is common to all in the nest, could reverse the order of their development. In the first nest examined we see the changes going on in the five individuals to be in continuous order, from the simple constriction of the larva preparatory to changing, to the completely formed mummy with pigmented eyes, and all of this in the order exactly opposite to their actual ages. The completed pupa, at the time of examination, was at the top, despite the fact that its egg had been the last deposited. Down the line the organisms were less and less developed, until in the bottom cell was the first-born just a little better than a larva.

A second *Odynerus* nest was found snug within an elder twig in Tower Grove Park on February 13, 1920. On March 31 it was found that the three pupae in the three cells were all fully developed, but by the degree of pigmentation of the eyes it was evident that this family, too, was in all readiness for emergence inversely to the length of time each insect had spent in development, just as in the previous twig.

The previous occupant of this twig (for all evidence was there that this family was not the first therein housed) had tunneled down only 2¼ inches. The mother of the present brood had not gone beyond this, but had put the mud floor for her first cell ⅛ inch above this terminus. The cells were rather small, only ⅜, 5/16 and 5/16 inch in length, and the pupae seemed crowded; I expected that these would prove to be either males or smaller individuals. There was an open gallery of ¾ inch at the top, which could have been used to afford more space to the inmates below if desired, or to make two additional cells if the mother had been so inclined. We shall not reproach her for omitting the additional cells, since she may have fallen victim to tragedy. But who are we that we should accuse her of lack of wisdom in crowding the other cells; she may have known her business better than we know. Fabre tells us about another creature that knows the sex of each egg, and builds a small chamber or a large one for it, according to whether it be male or female, and also supplies food accordingly. But on the whole, this nest was more carelessly constructed than the others; there was much rough pith remaining on the walls, with some mud and bits of old cocoons of other species still adhering; all this could have been scraped off, as in the other nests, and put into good roofs. Then these partitions, unlike the others, were very thin and frail, composed for the most part of mud. From examining this specimen, I conclude that the composition of the unknown substance in the partitions in some other nests in this species is the scrapings of the wall pith combined with the adhering bits of rubbish, cocoons and mud. Another noticable feature was that in this case we did not find the double partition walls, but instead the thin, frail, single ones, despite the fact that abundant material was at hand for the work right within the tunnel.

When we compare this slovenly specimen with the fine work of other members of this group, we see clearly that variation in behavior exists, and is due probably to individual temperament or experience. We note also the fact that some get away from the strict rule of always getting mud for partitions, but have "learned" that in cleaning out the cell it takes double work to carry out the rubbish and bring in new material; hence they have combined the two activities into one of actual utility. Here again is seen the process of learning, or, if one prefers to say it otherwise, the profiting from experience crystallized into frequent or customary action. In this nest also the vestiges of a cocoon varied; some had a complete head-piece, while others had only a thin dribble of cocooning substance varnished against the walls.

On April 12 they were still in the form of three perfect pupae; by May 1 they were fully pigmented, and on May 12 they emerged. The mica, which served as a transparent wall, was not securely sealed to the split twig, and they escaped from their cells sidewise without breaking the plugs, so I could not ascertain their normal mode of emergence.

Still another twig was opened on March 30, which contained four quiet larvae. This hollow twig also showed clearly that other wasps had been here to nest in days gone by, and had left numerous partitions with holes bored in their centers. This mother had not taken the trouble to clear out this debris, but had made cells above and below these ruins. In this large, hollow sumac twig was a floor of mud, placed 4½ inches below the top; a cell ⅝ inch in length built on top of this floor had one larva. The 1⅛ inch above that was empty, but contained the two old rings of mud, remains of previous cells; with little effort the new mother could have torn them away and made two cells for her young. This she did not do; hence I, prying into her home affairs long after, denounce her as a poor domestic manager. The four cells above this, each approximately ½ inch in length, contained four good larvae. The final plug was an inch from the top, and unlike the other series of cells, this had not a final plug directly over the opening. The vestige of cocoon-making was the same as in the specimens described above. Two weeks later the larvae were still quiet. The three uppermost ones emerged almost simultaneously, June 2 to 4, and the fourth, which lay in the bottom cell, was in all readiness to emerge when the twig was broken open on the latter date.

The last twig, which was opened on March 30, contained a tunnel 8 inches deep, which also had been made by other *Hymenoptera*. This new tenant, *O. conformis*, had likewise not carried the bits of mud and cocoons of parasitic *Diptera* outside, but instead had packed this rubbish firmly in the bottom of the tunnel. This made a mass 1½ inches deep, and at a point 2¼ inches above this she placed the floor of her first cell. The cells, five in number, were ¾, ⅞, ½, 9/16, and 9/16 inch in length, and a vacant chamber of only 3/16 inch just under the plug at the mouth of the burrow, had either been intentionally left empty, or was too small to be used for a chamber. The floor and partitions were 3/16, ⅛, ⅛, 3/16, ¼, ¼, and 1/16 inch thick, and were made in two portions or layers. The larvae were all naked, but in each cell was the usual vestige of cocooning, the instinct of which had long since lapsed. Even on March 30 I could see the beautiful transitions in the development of this series of five young wasps, just at the point of change from larva to prepupa. In the lowest cell was a quiescent larva of a creamy yellow color. In the next cell above, the larva was going through slow contortions at intervals, and the constriction at the back of the head was apparent. In the cell above this, the third larva had assumed a very definite pupal form; in the fourth cell the pupal development was more advanced, and in the fifth or upper cell, the development of the pupa was the same as in the last, with the addition of the pigmentation of the eyes, at that time a light brown color. This continuous series of changes, it will be noticed, is directly opposite to the order of the deposition of the eggs. This succession of development had brought them to maturity so that the last egg deposited was ready to be first to emerge as an adult, and the oldest egg was to leave the nest last! A wonderful adaptation for safeguarding the young at the critical time of birth! But how did it come about, and if an adaptation, why do not all the relatives follow the same advantageous principle? All of these wasps pupated with the head up, as usual. This order of development, the oldest in the bottom in the earliest stage and ranging to the youngest on top in the most advanced stage, continued unvaryingly through every stage of their development to adulthood and the point of emergence. Then, for reasons which I could not understand, the two uppermost died in their cells. The three lower ones broke through their own roofs, but, owing to the failure of their brothers above them to provide for them an exit from this point on, they all perished, imprisoned in the large middle cell. This is certainly bringing adaptation to a point of refinement beyond utility. It would be highly interesting to know whether those lower ones died in the middle cell after having escaped from their own because they did not have strength to break through the other parts above, or whether they simply did not have the wit to try. But whatever the cause, we are quite sure that they would leave no offspring to perpetuate their physical weakness or intellectual lethargy.

One dipterous parasite which emerged from one of these nests was identified as *Toxophora amphitea* Walk. [C. T. Greene].

The males of this species sleep in the low grass. I have taken them thus, about the middle of June, at two widely separated points, while sweeping the grass at twilight.

Odynerus (Stenodynerus) pennsylvanicus Sauss. [S. A. Rohwer.]

A twig of soft wood taken in a park in St. Louis on February 13, 1920, contained a brood of these wasps. By March 30 the three lower cells contained quiet young in the prepupal stage, all very much alike in the degree of development, and the top cell had a perfectly formed pupa, legs, antennae, etc., all yellow, with the eyes just taking on a little darker shade of yellow preparatory to becoming pigmented. This latter one was injured in cutting the twig. The stalk was provided with a transparent wall and the occupants were watched to see if they would mature in the inverse order of the deposition of the eggs—the last egg to become the first-born and the first egg to become the last to emerge.

This twig had not been excavated by the mother of this brood, but had been used previously by some other occupant. The four cells measured ½, ½, ⅝, and ⅝ inch in length; the plug serving as a floor and the partitions were ⅛, 3/16, ¼, 3/16, and ⅛ inch, the last serving as a roof. There was a vestibule of ¾ inch above this, and it had no mud plug over the opening. Here, too, I found the vestige of a cocoon in the form of a thin covering, the edges of which adhered to the round wall of the channel. In one case this disk was directly above the head, and in another it was plastered against the ceiling. In one of the other two it was in the same form, but much abbreviated, and the surplus splashed on the side of the cell; in the other and last cell it consisted of only a trace of the material splashed against the wall. This series shows the last vestiges of what was once probably the important habit of cocoon-making. By April 12 the three lower ones had arrived at the pupal stage; the upper one had died of its injuries. On April 26 the condition was precisely the same. By May 1 these pupae still were yellow, but their eyes were pigmented; by the 12th they were all black. They could not be examined again until May 26, when it was found that in the interval all had attained complete development, but for unknown reasons all had perished without breaking their walls.

Another sumac twig harboring this same *Odynerus* was found in the same park on February 12, 1920. The hollow in the twig was 4½ inches deep, and contained six large, roomy cells with six fat and thriving pupae. The mother of this brood left a record of her individual temperament, in contrast to nests heretofore examined, by making cells of various sizes, from ½ to 1 inch in length. The partitions varied from ⅛ to ¼ inch, and each one was constructed of two layers, but these two layers touched each other, with no free space between. The material from which they were made was the debris which had formerly adhered to the walls, and which had been scraped off clean and kneaded into a mass. In one partition made of these scrapings was a perfect brown cocoon of a parasitic wasp imbedded firmly in the pulp. This shows how little regard the wasp paid to parasites' cocoons when she needed building material. This cocoon was not injured and later gave forth a good adult. Some of these wasps had the aforementioned remnant of cocooning substance in a sheet stretched over the head, and in some this material had been dissipated while still liquid on the walls. In three of the cells, behind each occupant was a pretty spiral curlyqueue of thin, papery substance; this evidently was also cocooning material thrown out in clearing the alimentary tract for pupation, but without any attempt to utilize it for a cocoon.

By April 12 all seemed equally well developed excepting in the pigmentation of the eyes; in this detail, one could see a regular gradation of color from light brown to black, appearing in a continuous series from the bottom upward, or inversely to the order in which the eggs had been deposited; that is, the last egg deposited showed the most advanced degree of development. Two days later the lowermost two were still creamy white pupæ with the eyes highly pigmented; the third was black with the legs still white; the fourth, strange to say, was a little lighter; the fifth likewise was in a transition stage of pigmentation, but darker, while the sixth was entirely black, with only spots on the lower abdomen where close scrutiny revealed that the pigment was still thin. By April 30 all were fully pigmented and mature, and only the bottom one had the legs still adhering to the sides of the body. The fourth, which at the last examination had vexed us because it broke our pretty sequence, was now dead; its slowness in developing was probably due to a diseased condition of the larva, and not to a break in the laws of inverse priority.

On May 11, I discovered that all were dead excepting the lowermost one, which virtually was hopelessly imprisoned beneath the long tier of unopened cells. In cells 2 and 3 the partitions above were bitten and perforated, which shows that these wasps had attempted to emerge normally, but had found the way above them blocked. The lack of moisture may well be a factor causing hardship in their emergence in abnormal surroundings; in the open fields the twigs are normally exposed to an abundance of moisture at that time of year.

From the foregoing evidence we may conclude, therefore, that in this species the topmost individual matures before the lower ones, or the last egg deposited is the first to become adult.

Odynerus leucomelas Sauss. [S. A. Rohwer].

A sumac stem taken at Clifton Terrace, Illinois, in November, 1916, contained a hollow which was beautifully partitioned with mud plugs. One cell contained a pupa which developed into an adult *O. leucomelas* and emerged on April 12, 1917. A parasite, *Epistenia osmiae* Ashm., emerged on May 20, 1917. Fig. 51 shows the stem split open, with the mud partitions and the two filled cells; the lower one is the cocoon of the parasite.

A second stem taken at the same place had nine cells, all likewise beautifully partitioned with mud; one cell contained a dried caterpillar, and others had living pupae, which gave forth two adults on April 14. One pupa was not encased in a real cocoon, but was thinly but completely covered with a transparent veil. That the cocoon making habit is waning and probably of no utility to the species is obvious when one finds cocoons started but not finished, and often the cocoon substance is dissipated on the walls of the cell. Another cell gave forth an adult cuckoo-bee in June, identified as *Chrysis (Tetrachrysis) sp.* [S. A. Rohwer].

Odynerus foraminatus Sauss. [S. A. Rohwer].

The nest of this wasp was found in a large sumac twig, ¾ inch in diameter, containing a burrow ¼ inch wide, which afforded a roomy and protected nest. It was a tall stalk, in which the hollow went down to a considerable depth. Only the top 5½ inches of the cavity was used by this wasp, however; at that distance from the top she had laid her floor. Below this were evidences of old mud partitions, showing that this mother was not the first to use the abode, but that she had adapted the ready-made tunnel to her needs. Even at this point it is possible to perceive the differences between this and the sister species, *Odynerus (Stenodynerus) pennsylvanicus;* these larvae seem larger, and the cauls or partial cocoons are larger; moreover this material looks more like silk spun from glands, probably in the mouth, whereas in the pupae of the other species it appears that the vestiges of cocoons are from material from the alimentary canal. Bits of this material from the nest of *O. foraminatus,* examined under the microscope, show silk-like threads crossing and recrossing in every direction. I do think, too, that into this network the material from the alimentary canal is injected, as in *Trypoxylon politum* and *Chalybion caeruleum.* The cocoon of *O. pennsylvanicus,* under the microscope, shows the same silky condition, excepting that, at least in my sample, the silken threads are fewer and the filling substance or varnish more plentiful. The cocoon of this species differs from that of *O. pennsylvanicus* also in that this material forms not only a cap, but also something which has the semblance of a cocoon extending under the body and sometimes around the dorsal side.

The partitions in this nest were made of mud and possibly the remains of debris that the mother found in the tunnel, and also seemed to be made in two parts, as described for *O. pennsylvanicus.* In the upper four cells of this series, these two walls forming each partition were very close together; in the two lower ones, the space between the two layers was much greater, one measuring 5/16 inch and the other ¼ inch.

At the examination on March 30 the lower four organisms were typical quiescent larvae, all very much alike, while the two upper ones were perfect pupae, with wing-pads becoming slightly brown, and the eyes pigmented. Just two weeks later, April 12, it was found that two of the four lower ones had changed to pupae; they were not the first and second, however, but the second and fourth from the bottom, leaving the first and third still larvae, the first in the earlier stage. On April 15 the conditions were still the same, the first and third still larvae. By May, the third had pupated; the fifth and sixth were entirely black. By the middle of May the two uppermost had emerged; the third from the bottom, the unfortunate laggard, was dead in the twig; the bottom one had at last become a black pupa. The wasps in emerging had demolished the roofs above their heads. The last finally emerged on May 31. Thus the entire family developed and emerged in sequence from top to bottom, excepting that the third lagged in its development until its death.

Another twig contained a nest in all essentials similar to that described above. It was accidentally placed upsidedown in its jar. When the young wasps emerged they bit a disc out of the mud next to their heads, making a round hole in the partition through which they emerged, head downward. This certainly indicates, contrary to Fabre's suggestion, that the force of gravity has nothing to do in guiding their emergence.*

Stenodynerus zendaloides Robt. [S. A. Rohwer].

Unlike other wasps, this species uses both pith and mud in nest-building. The mud helps the cocoonless wasp to survive, in that it is worked up into a sort of cocoon

*For additional facts on the life history of this species see our "Wasp Studies Afield," 334-340, 1918.

either by the larva or by the mother. Certain of the Eumenidae, of which the genus *Odynerus* is one, make no cocoon, or at least a very poor one, before pupating. But here in this species we have a twig dweller that uses mud in an entirely new way, in that the mother supplies the dirt, and the larva somehow manipulates it into a cocoon.

In 1917 one elder or sumac stalk, in 1919 three stems, and in the winter of 1921-22, two twigs were taken at Wickes, all of which harbored this species. The tunnels in these twigs had undoubtedly been dug out by the mother *Odynerus;* in this respect her work is very unlike that of certain other species of the genus, which habitually use old abandoned tunnels. She is unlike her sister species, too, in her method of using her mud. It will be remembered that others, such as *O. foraminatus,* etc., bring in wet mud and make partitions of circular discs, two of which (one at either end) make one room; since these rooms or cells are close together, end to end, their end walls are almost in juxtaposition, and really form a partition of two thin walls between the cells. When we examine the nests of this species we find the partitions made of pith, and between these partitions is a mud cocoon and an empty space (see fig. 52). Now these cocoons of mud are very puzzling, since it seems they can be made only by the larvae, and the mud must be supplied by the mother, since obviously the larvae cannot fare forth to gather mud. One might find a different explanation for the phenomenon but for the partitions of pith and the hollow space above each mud cocoon. The whole arrangement of the nest is so complex that with a limited amount of material I am unable to work out a final and logical explanation for the entire scheme of nidification. For the present the best I can do is to record the details at hand, in the hope that additional data later will reveal the system in this complicated piece of work.

One tunnel containing five cocoons ("A" in fig. 52) was 12 inches in length and approximately ⅛ inch in diameter. The bottom half inch was filled with finely bitten pith; the cell above it was one inch in length, the lower half of which was filled snug with a cocoon made of earth, and the upper half was empty, but the walls were dirt-smeared. It seemed that in all probability the mother had made this room thus, filling the lower half with egg and provisions, and the upper half with dirt, so that the full-grown larva, when ready to pupate, could pull the loose earth down around itself, moisten it somehow and with body contortions shape a cocoon against the sides of the cell. The outside of this cocoon was rough and granular, while the inner surface conformed to the shape of the occupant's body, and was glazed with some substance which made it smooth and brittle, though more tenaceous than mud. It is reasonable to surmise that in this species, as in many others, the excrement that accumulates in the body during larval growth is at the time of pupation ejected in toto and is worked to a smooth, glazed surface. While the sides and bottom of the cylindrical cocoon were outwardly rough with natural granules of dirt, the top (headward end) of the cocoon was a transparent disc, made either by spinning or by skillful manipulation of the varnishing material. Exactly these same conditions were present in all five of the cocoons which utilized the bottom 8 inches of the tunnel. Above the open space of the top one was a plug of mud, loosely thrown in, an inch deep, and then an empty channel to the top.

Other nests were similar in the nature of their construction, so a record of the proportions and materials will suffice for comparison. In the bottom of one 8½-inch tunnel was a half inch of broken pith, a cell with a cocoon of mud with papery or glazed lining and an empty space equal to the length of the cocoon; above this was a papery partition, and on top of this a layer of dirt which had been dropped and lightly packed in —not plastered like masonry—a plug of pith ⅛ inch thick, an empty cell 1 inch long, another papery roof over this, and a mud plug of ⅜ inch depth on top of this. This upper cell had been left empty and terminated this small nest. Another, in an elder stem this time, began at the bottom with the usual pack of pith chips ½ inch deep, then a cell containing its cocoon and some additional space, a roof over this and a pack of pith ⅛ inch thick, topped with a layer of mud ¼ inch thick; another cell with its roof this time of mud ⅛ inch thick, and a layer of pith ⅝ inch, another layer of mud 5/16 inch and again pith ½ inch; a third cell ½ inch long covered by a mud roof ¼ inch thick, another cell with a roof of pith ½ inch, and beyond this the open hollow of the stem for several inches, showing all along its length the horizontal jaw-marks where the pith had been torn out.

Any attempt to formulate rules or system from such chaotic data is obviously absurd. It may develop later that the mother wasp oviposits and provisions the cell and then fills in the upper part with dirt which the larva at pupating time pulls down around itself to make its cocoon, and that sometimes it tears down the whole supply, clear to the pith or papery partition, and sometimes it leaves a part of the dirt adhering to the roof, forming a mud layer. On the other hand, it may become more apparent that this wasp is a versatile little creature which can use either mud or pith with equal ease, according to its availability. Someone might suggest that a simpler interpretation would be that the mother wasp uses pith for partitions, then brings in mud and actually lines the cell with it, making a cocoon for the larva after it has devoured its provisions, and then the mother, having the mud at hand, goes on using it in some cases in lieu of pith for partitioning material. The only patent point against this simple theory is that in the lining of the roof of the cells is a papery or woven disc, almost transparent, which could not possibly have been woven by the mother.

On three occasions during the past three years I have removed coleopterous larvæ from the nests of these wasps. These were submitted to Dr. Böving, who has identified them as the larvæ of the leaf-miners of the genus *Chalepus,* and thinks "that they may possibly be *Chalepus scapularis* Oliv." Of course, since this wasp uses burrows made by other insects, I have no absolute proof that the *Odynerus* mother stored these beetle larvæ, but since she handles other problems of nest-building in an unusual way, I should not be surprised if she did the unusual thing in provisioning.

The normal dates of the emergence of this species as I have observed them are May 18 to June 15, with the largest numbers on June 8 and 9.

The parasites which emerged from the nests were *Toxophora amphites* Walk. [C. T. Greene], *Foenus tarsitorius* Say [R. A. Cushman], *Epistenia osmiae* Ashm. [S. A. Rohwer], and *Chrysis (Olochrysis) sp.* [S. A. Rohwer].

Stenodynerus vagus Sauss. [S. A. Rohwer].

An elder twig taken in Shaw's Garden on July 4, 1918, had partitions of mud and two cells; the upper one was filled with fifteen caterpillars, all of one species of *Tortricidae* [S. B. Fracker] and the lower cell contained a full-grown larva. The following day, at 11 p. m., I found that the larva had lined the nest with what seemed a papery material. This was not spun, for if it had been the cover-glass which replaced the part of the twig which had been cut away would have had a covering also; as it was, only the walls were covered, or one might say washed, with the substance.

Another specimen of this species was found alone and dead in an elder stem on May 2. There were no cells in the hollow of the twig, and it seemed quite probable that it had gone in for shelter from the cold the previous autumn and had died with the oncoming winter.

Odynerus (Ancistrocerus) capra Sauss. [S. A. Rohwer].

The nest of this species was in a sumac twig taken November 19, 1919. The tunnel, ⅛ inch wide, had been formerly used by a *Ceratina* bee. The present occupant had enlarged the upper portion to a width of ¼ inch and had inserted mud partitions. The two cells were ¾ and ½ inch deep. The larvæ had no cocoons, but the walls were thickly plastered with some semi-transparent varnish.

By March 31 the organism was completely formed and moved in the cell, but made no attempt to force its exit until April 9. On that day it bit its way through the mud plug and came out. For the first two days it would readily lap saliva from my finger-tip, and after that it lived on molasses until April 19.

Interesting details on nest-building of this species is given by L. H. Taylor in Psyche, *29:* 56-58, 1922.

CHAPTER VI.

THE PATRIARCHATE WASPS OF THE GENUS TRYPOXYLON.

Trypoxylon clavatum Sm. [S. A. Rohwer].

Other wasps are matriarchate, but in several species of this genus we first find them patriarchate. Of the large number of species of wasps described, none outside the genus *Trypoxylon* are known to exhibit paternal solicitude. *T. clavatum* certainly displays this unique characteristic. The Peckhams[1] have described how the nests of *T. rubrocinctum* and *T. albopilosum* are protected by the males, and elsewhere we describe this behavior for *T. albopilosum* and note for this species that mating often occurs when the female enters the burrow. This same behavior of the male has been described by Hancock[2] and Rau[3] for *T. albitarsis (=politum).* Hartman[4] finds that the males of *T. texense* remain faithfully on guard in the nest during the absence of the female, although he also finds a large proportion of nests without males.

During the period of study, *T. clavatum* gained a fairly good foothold in the clay bank, which was already beset with parasites belonging to a dozen species. Many of the empty burrows of the mining bees afforded very comfortable nests for the young of *T. clavatum.* I was somewhat surprised to find them in this habitat, since previously I have recorded them as clearing out and utilizing old beetle burrows in wood, old nests of the mud-daubing wasps (*Sceliphron caementarium* and *Trypoxylon albitarsis=politum*), and on one occasion they

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[1] Wasps, Social and Solitary, pp. 190-194. Also *Bull. Wis. Geol. & Nat. History Surv. Ser.* I, 2: 77-87.

[2] Nature Studies in Temperate America, pp. 210-212, 1911.

[3] *Journ. Animal Behav.* 6: 27-63. 1916

[4] *Bull. Univ. Tex.* 65: 57-60. 1905.

were seen carrying out load after load of sawdust from a burrow in a log which they were enlarging by biting out the wood. These instances, together with their present occupancy of the abandoned bee holes, shows wide diversity in their selection of home sites, and willingness to take almost any ready-made domicile and make it over rather than to carry mud and build, as do their pipe-organ-nestbuilding sisters. Yet after all there is a kinship to this mudnesting species, for *T. clavatum* carries mud to partition and plug up the tunnel that she has appropriated for herself. This diversity in selection of habitat is very interesting in that it mirrors the versatility of nesting habits in the genus, or rather the family, since this consists of but one genus. If we consider other genera of wasps, such as *Pompiloides,* or *Sphex,* or *Chlorion,* we find that all the members of each group nidify in a similar manner. But here in *Trypoxylon,* we find certain species building nests of mud, *e. g., T. albitarsis* =*politum;* some live in stems of plants, as *T. frigidum* in syringa stems (Glover, Rep. Com. U. S. Dept. Agr. 1877, p. 104) and stems of sumac bushes (Peckhams, Wasps Social and Solitary, p. 194); *T. figulus* uses holes in posts and straws in thatch (Westwood, Introd. *2*: 194. 1840) and in the galls of *Cynips kollari* (Billups, Entom. *28*: 47. 1895) and was seen to enter nests of *Odynerus reniformis* (Morice, Ent. Mon. Mag. *42*: 216-220. 1906); *T. johnsoni* in stems of soft wood (Rau, Wasp Studies Afield, p. 137-139), and in the soil clinging to the roots of an upturned tree (Rau, Trans. Acad. Sci. St. Louis, *24*: 22. 1922); *T. aurifrons* "constructs its clay cells in the shape of water jugs" with a distinct neck and well-formed mouth (Step, quotes Bates, Marvels of Insect Life, p. 426), and cells or tubular structures, building rows of them together in corners of verandas (Weed, Insect World, p. 198. 1907); *T. tridentatum* uses the pith chamber of elder twigs (Rau, Wasp Studies Afield, p. 134); *T. collinum* Sm. was seen to enter a burrow probably made by some other insect in hard sand (Ashmead, Psyche *7*: 45. 1896); *T. attenuatum* emerged from perforated bramble stems (Saunders, Trans. Ent. Soc. Lond. 1880. p. 278); *T. clavicernum* nests in posts (Morley, Entom. *31*: 14. 1898) and inhabits galls of *Cynips kollari* (Billups, Entom. 28: 47. 1895); *T. rubrocinctum* and *T. albopilosum* nest in posts (Peckhams, Psyche 7: 303. 1895), and *T. rubrocinctum* was found in an elder stem (Rau, Trans. Acad. Sci. St. Louis *24*:22. 1922); *T. corinifrons* takes up its abode in round holes made by Scolytids in pine timber (Ashmead, Psyche *7*: 45. 1891); *T. texense* occupies small crevices in wooden or stone walls, beetle holes in cedar posts, unoccupied cells of old mud-daubers nests, holes mechanically bored in blocks of wood, and empty shot-gun shells standing upright (Hartman, Bull Univ. Tex. *65*: 57-60. 1905); and in clay banks, using tunnels dug by bees (Hungerford and Williams, Ent. News *23*: 248-249. pl. 16); *T. cockerellae* resides in the old nests of the mud-daubing wasps (Rau, Journ. Anim. Behav. *6*: 36-42. 1916); *T. rufozonale* was dug from its nest, a hole in a clay bank, (Smith, Univ. Nebr. Stud. *8*: 30. 1908); *T. rejector* builds its own cells and is also in the habit of appropriating those of other insects (Horne, quoted in Wood, Insects Abroad, p. 477); *T. alternatum* uses stems of roses and brambles, the cells separated by walls of sand (Wood, Insects Abroad, p. 477); *T. scutifrons* and *T. errans* were induced to make their cells in glass tubes (Wheeler, Sci. Monthly *25*: 86. 1922); *T. figulus* uses galleries she does not herself dig (Fabre, Bramble Bees and Others, p. 102. 1915); *T. excavatum* Sm. nests in stems of syringa (Rohwer, Bull. Conn. Geol. & Nat. Hist. Surv. *22*: 676. 1916); *T. plesium* nidifies in twigs; *T. leucotrichium* builds in hollow twigs of bamboo (Howes, Insect Behavior, p. 40. 1919); *T. cinereohirtum* builds nests in nail holes, spools, glass tubing, (Howes, Insect Behavior, p. 27. 1919); *T. intrudens* "hatched from the mud cells made by *Parapison rufipes* (Wood, Insects Abroad, p. 471); *T. brevicarinatus* forms her nest beneath a palm leaf, and may cement together as many as twenty-five cells (Bodkin, Ent. Soc. Lond. 1917: 297-321, *fide* Williams); *T. elongatum* nests in bamboo twigs lying on the floor of a ravine (Williams, Phillippine Wasp Studies, p. 143. 1919); *T. pileatum* uses ready-made cavities and makes mud partitions; sometimes the mother digs her own tunnel in twigs. (Dutt, Mem. Dept. Agric. India *4*: 201. 1912).

With such a variety of methods of nesting within the single genus, one sees in *T. clavatum* an indication of an unstable condition of the species. Either all cell-like places are equally good for the development of the young of the species, or natural selection has been lax in eliminating the individuals which chose the less favorable nest.

But let me return to *T. clavatum* as for the time the center of my study (fig. 53). The clay bank was an exceptionally fine location, with the sheltering porch overhead, and facing the morning sun, and with foliage and a dozen old buildings near by to harbor spiders. So, with the additional advantage of having the male present to keep out the parasites, it would indeed have been surprising if this species had not gained a good foothold.

The *T. clavatum* made their appearance in the clay bank June 26, 1917, and were present throughout the summer until late autumn without interruption, excepting a short period late in July, that period probably being the time between the last of the first generation and the first of the second generation. At the time of their discovery, three nests were found, all containing guards. Two of the apertures were small enough to nicely fit the head of the male watcher; the third was entirely too large, and the little head looked comically lost in the cavernous hole over which it kept solemn guard. This male evidently realized his condition, if one may use such terms, and would not put his head to the opening as did the others, but remained on guard an inch or so within the burrow, where his comical triangular face could be seen. In one of the other nests, the silvery face of the male could be seen at the orifice for hours, keeping out intruders, although the only impostors that seemed to bother were members of its own species. The female, of course, is usually out foraging for spiders or getting mud for the partitions while the male is busily at rest. These wasps move with stiff, angular, jerky movements, and often poise in the air like a hummingbird for several seconds before entering the nests. Often the female will rest for several seconds at the opening, shaking antennae as if communicating with the door-keeper. This may be a secret sign, for then out he comes, mounts her back, and thus they enter. Sometimes the smallness of the aperture forces him backward, but he clings as best he can. In all of the nests observed, a male was always on guard; this was in contrast to *T. texense*, observed by Hartman where the male was only occasionally present.

For three days I had the opportunity of watching one nest of *T. clavatum* very closely, while waiting for the return of some bees that had been taken out in homing experiments. During this time, this male did not once leave the burrow; he stood guard bravely, and often assisted the mother by relieving her of the spider as she reached the doorway. With a loud hum he would carry it back into the burrow, while she would go searching for another. I fell to wondering how he could get his own food under these circumstances, and watched closely to try to learn; after three days' observation I am inclined to think that his spouse brings his food in to him. Often when the female came in, the male placed his mouth to hers for several seconds, in precisely the same manner as do the *Polistes rubigenosis* when they pass food from one to another.[5]

None of the writers who find the males present in the nests of the various members of the genus *Trypoxylon* mention the behavior of mating which occurs, as I relate later, in *T. albopilosum,* and which is much more pronounced in the species under present discussion, *T. clavatum.* Perhaps in the individuals discussed by Hartman and the Peckhams, mating did not occur at the nest; it could hardly have been overlooked by observers so keen. If it does not occur in *T. rubrocinctum* and *T. texense,* and occurs slightly or not at all in *T. albopilosum,* and very strongly in *T. clavatum,* then one sees within the genus continued progress in this habit along evolutionary lines. If one could correlate this habit with the phylogenetic succession of the various species, one would get extremely interesting data showing that habits as well as structure follow evolutionary lines.

It is indeed pretty to see a female lightly carrying her gaily colored spider beneath her body, oscillating on the wing before the hole, where gleams the stolid face of her mate; she touches or vibrates his antennae with her own as if in delicate greeting, and flies back a little; the male follows her with his eyes, alertly cocking his head this

[5] To be published later.

way or that, before he condescends to come out and let her in. Sometimes he takes his time about even granting this favor.

On June 29, at 8 a. m., I was attracted to a jumble of life at the entrance to one of the nests. After some seconds I analyzed it; it was a mother *T. clavatum* working outrageously hard to push in a large spider that was wedged in the doorway; the spider seemed much too large for the burrow, and she was having a hard time indeed to get it in. She got no assistance from "husband, father, protector", but instead he insisted upon playfully riding on her back and eventually suceeded in mating. She did not chase him away, neither did she stop to pay him any heed, but regarded him with tolerance that looked almost like indifference. She eventually succeeded in her difficult undertaking, and she did it by sheer perseverance and industry. Perseverance and industry are the terms which especially apply to this mother, in contrast to the higher psychical behavior of two of the Pompilid wasps which, when confronted with the identical problem of getting their prey into a burrow too small for it, enlarged the burrow. However, since this species does not instinctively dig, one could hardly expect it to modify its instinct in time of trouble. And yet, was there not in her action a glimmer of intelligence, a little variation from her usual mode of action, brought about by an attempt to overcome a new difficulty by summoning as resources all of the methods she practises in other situations? Her method, we should explain, was to push, pound and butt the spider into the hole with her head, instead of flying in with it as she normally does. Of course the "instinct-monger" will immediately say that it is her custom to pack the spiders close together in the cell by this same method, so she is already familiar with the process. But it seems to me that, as mentioned above, when she transfers the method to a new environment and circumstances, she has gone beyond pure instinct and, with an instinctive inclination toward pounding, she has broken the chain of instinct and used a grain of something akin to reason. After the spider had been laboriously forced into the burrow, the male blithely followed in after.

Since the male follows the female in entering the burrow, he is the first one out, with the female following immediately after him. She flies directly away about her business, while he returns to the opening, turns around and creeps in backward.

The male is a good watch-dog. I have never chanced to see a parasite attempt to enter the burrow, but I have often seen other *T. clavatum* try to intrude. On one occasion, when the little watchman had an exceptionally difficult task to keep out another male, he eventually got the impostor by the back of the neck and actually threw him out, with quite a scuffle in the air before one entered the burrow again; but whether it was the owner or the intruder that returned I do not know, since their identity was lost to me in the fight. Not to be outdone, the vanquished one returned after a few seconds, but even before he could put his foot in the doorway, the occupant flew out and chased him some distance, quickly resuming his place on guard. This probably was the original occupant, for soon after, when the female returned, she was greeted with calm familiarity and entered with the usual ceremonies. A half hour later, this or another rival again disturbed the peace of the home, but the owner at once flew menacingly at him and promptly put him to rout.

It is not alone the males who try to gain access to the nests of others; the females, for reasons which I have not yet ascertained, often try to force their way in. On three occasions during a single afternoon I saw a little male sit tightly in the doorway when strange females tried to enter his burrow. One persisted in her attempts for five minutes, but he was immovable. Another attempt was made when his wife was within, so there may have been reason for his behavior.

The males of this species are faithful to their task, and leave their post only for good reasons. When one attempts to get one of them out, he stealthily walks back deep into the burrow. On one occasion, when a male was busy chasing away a rival, I quickly plugged the hole with cotton; when he returned he could not back down, so I took him in a test-tube to make sure of his identity. After ten minutes I released him, whereupon he went direct home and crawled deep down into the burrow, and for fear would not show his face. Even the returning female had great difficulty in arousing him. She flew back and forth before the burrow, then flew away to other holes and attempted to enter (is it possible that the face of her mate is one of the "landmarks" by which she identifies her own home?), then finally returned to her own, and by vigorous flapping of her wings at length aroused him to come out so she could enter with her spider. Even after she left, for many hours, the terrified little male kept 'way down in his retreat, seldom even putting his face to the doorway.

I have always had a great desire to see the moving day performance, when the provisioning is completed and the nest must be closed up and left. Does the male hover near while the female plugs up the burrow, or does he scout about for a new nesting-place or a new mate? Do both leave together, or does the female carry her partner on her back, or do they behave like certain birds which, after nidification, divorce each other and find new mates with the beginning of a second brood? One may speculate for hours on how the house-hunting and removal may occur, when one lucky chance of being on the scene at the right time may clear up all the mystery in a half hour.

There are at least two generations of *T. clevatum* per year, the first generation in June, as I have recorded them here from the clay bank and from the cells of the mud-daubers' nests, and the second in later summer, having emerged as adults in August.

The members of this species, as I have stated early in this chapter, select whatever ready-made homes they can find, the old cells of the mud-daubing wasps, (fig. 54 shows a section of a *Sceliphron* nest; "a" has the cocoon and debris *in situ,* and "b", removed to show the mud partitions), holes in posts and logs, etc. These she divides into rooms by partitions of mud which she carries from afar. In using the old cells of mining bees, her method is hardly different. One nest contained seven cells, as illustrated (fig. 55B). The burrow was ¼ inch in diameter, 3 inches long, with a branch 1½ inches in length. The opening was plugged with mud, and the two first small cells were empty. I always found one or two cells near the entrance empty; these I called, for want of a better name, air-chambers. The next five cells contained spiders and eggs or larvae. The contents of the first cell were lost, but the second one had ten spiders and a young larva; all spiders were apparently dead, since none responded to stimulus, but all were plump and fresh. The next cell contained nine spiders, which also were freshly killed, and only one gave very slight response to stimulus. A very small larva was attached to one of the spiders. The fourth cell had ten freshly-killed spiders, none of which responded to stimulus, and an egg cemented to the dorsal part of the abdomen of one. The fifth cell contained ten spiders, only the two smallest of which showed signs of life. The egg of the wasp was attached across the dorsal surface of one of the spiders. In three of the four cells it could be definitely ascertained that the egg had been placed on the last spider brought in, which shows that, unlike some other species, this wasp provisions its cell up to the closing point before it deposits the egg. It is interesting to note that only two of the very smallest spiders were in condition to respond to stimulus, when one might logically expect that they would be less able than their large companions to withstand the effects of the sting. Is it possible that, since they were so small, they were deemed unworthy of a sting and were thrust in with none, or only a slight one?

Another bee burrow used by *T. clavatum* was 2½ inches in length and contained only two brood cells (fig. 55C). Immediately below the plug was a half-inch air-chamber (x), then a plug of mud, and then the cell, which for half its length was a bee cell with its characteristic varnished walls. The passage narrowed again and was plugged, and beyond this was a second occupied cell. The lower cell contained eight spiders, small and medium-sized, some of which were rather active; the egg was sealed to the abdomen of the uppermost. The upper cell had seven spiders, four of which were large and three of medium size; the large ones and two of the small ones were dead; again only one small one, *Misumena oblonga* [J. H. Emerton] responded to stimulus.

Another nest was a typical bee burrow (fig. 55A), modified with two empty air spaces (x) next to the mud-plugged entrance, and eight cells of *T. clavatum* formed by partitioning off the remainder of the tunnel. The outer surface of all the partitions was very smooth, while the inner surface, the side which was away from the wasp as she worked, showed each load of mud clearly distinguishable in little ridges. The entire burrow was about 4 inches in length and 5/16 inch in diameter. The cells were opened, of course, in the inverse order to that in which they had been made and filled. The first emptied (the last sealed) contained eleven spiders, of several species, and an egg on the last one brought in. Not one of the spiders seemed to be alive. The next cell had nine spiders and a small dead *T. clavatum* larva. The next, the third from the top, had eight spiders and a larva one-fourth grown. The fourth contained four whole spiders and parts of as many more, and a *T. clavatum* larva one-third grown. The fifth cell had only three spiders remaining and a large larva; the sixth cell contained ten spiders but no egg or larva. The seventh cell harbored a larva more than half grown and only one remaining spider, while the eighth cell was sealed with only six spiders and no egg.

This was no simple task for so small a wasp to accomplish—the preparation of eight cells for her nest and provisioning them with approximately seventy spiders. The task may be easier, or on the other hand it may be more difficult, because of her habit of gathering not one species only, but a great variety of spiders. If she hunts them merely by prowling and blundering about, then it is of great advantage to her that she can use a variety of prey. If her habits or instincts were refined enough to lead her to go again and again to the peculiar habitat of some species, as some wasps do, then much of her rambling and hunting would be saved. Thus in the wasp, as in the human species, it remains a question whether a high degree of specialization, i. e., refinement in one limited direction, is a mark of superiority or of degeneration. It is marvelous indeed to see a wasp go direct to the plant or the environment of the one species which is her prey, capture it and bring it home with scarcely a false move, and return for another just like it. And yet, in all seriousness, should this type of ability really be classed as superior to that of the wasp which, while lacking this wonderful ability to find and handle one species with such a fine degree of accuracy, yet can go out boldly into a number of environments, meet a dozen different kinds of adversaries with as many different ways of fighting, sting a dozen different species and bring them home in any way she can? Diversity of prey means diversity in methods of search and handling—a time-consuming piece of business.

The contents of the three nests described above will give the reader an idea of the variety of spiders stored.

In nest 55B, the spiders which could be identified:

Second cell,

2 *Philodromus pernix* Blackwell [C. R. Shoemaker].
5 *Gayenna pectorosa* Koch [C. R. Shoemaker].

Third Cell,

6 *Gayenna pectorosa* Koch [C. R. Shoemaker].
2 *Epeira parvula* male and female. [H. J. Emerton].

Fourth cell,

1 *Xysticus gulosus* Keyserling [C. R. Shoemaker].
6 *Gayenna pectorosa* Koch [C. R. Shoemaker].
3 *Epeira*, young of 3 species [H. J. Emerton].

Nest 55C:

First cell,

1 *Misumena* sp. [C. R. Shoemaker].
1 *Phidippus* sp. [C. R. Shoemaker].
4 *Dendryphantes militaris* Htz. [C. R. Shoemaker].
1 *Misumena oblonga* male. [H. J. Emerton].

Second cell,

1 *Synema parvula* Htz. [C. R. Shoemaker].
3 *Phidippus* young [H. J. Emerton].
2 *Dendryphantes aestriolis* [H. J. Emerton].
1 *Dictyna* sp. female [H. J. Emerton].
1 *Leinypha* sp. [H. J. Emerton].

Nest 55A:

First cell,

2 *Oxyopes salticus* Htz. [C. R. Shoemaker].
1 *Maevia vittata* male [H. J. Emerton].
2 *Menemerus binus* male [H. J. Emerton].
3 *Epeira foliata* [H. J. Emerton].
1 *Dendryphantes* sp. [H. J. Emerton].
2 *Phidippus sp.* young [H. J. Emerton].

Second cell,

2 *Epeira placida* [H. J. Emerton].
4 *Dendryphantes astatvorlis* [H. J. Emerton].
3 *Phidippus* sp. [H. J. Emerton].

The spiders of the next three cells were lost.

Sixth cell,

3 *Dendryphantes destrivorlis* [H. J. Emerton].
3 *Zygoballus bettini* [H. J. Emerton].
2 *Phidippus* sp. young [H. J. Emerton].
2 *Misumena* sp. [C. R. Shoemaker].

The contents of the seventh cell were lost.

Eighth cell,

1 *Zygoballus bettini* [H. J. Emerton].
2 *Phidippus* sp. young. [H. J. Emerton].
3 *Sassacus barbipes* P. [C. R. Shoemaker].
The three nests above were opened on July 2.

Another nest of two cells was opened on September 4, and gave:

7 *Misumessus asperatus* Htz. [C. R. Shoemaker].
1 *Dolmedes,* perhaps *idoneus* [H. J. Emerton].
2 *Dendryphantes militaris* [H. J. Emerton].
1 *Theodina puerpera* young [H. J. Emerton].
6 *Phidippus* sp. [H. J. Emerton].

A glance over the names of the spiders will show the large variety taken, despite the fact that I have recorded the work of only four mothers, and yet one can see the tendency of the mothers to show individual preferences. For instance in nest 55B, of the 25 spiders collected by this mother, 17 were *Gayenna pectorosa,* and no other mother, even though hunting at the same time in the same region, had any of this species, and aside from 5 specimens of *Epeira* which occurred in other nests, the other species, *Philodromus pernix* and *Xysticus gulosus* have not been found in other nests.

In nest 55C, of 15 spiders taken by the mother, 6 belonged to the genus *Dendryplantes,* 4 to *Phidippus* and 2 to *Misumena,* but this shows no individual taste since the same species appear in the contents of nest 55A.

In nest 55A, 36 spiders cover a wide range of nine genera and about twelve species. This mother was not so fastidious. The most of any one kind was 9 from the genus *Phidippus;* hence I conclude that she was easily adaptable in her choice of spiders.

The fourth nest taken later in the year contained in its two cells 17 spiders, 6 of which were *Phidippus* and 7 *Misumessus*.

One of the most neglected and difficult aspects of wasp behavior is the observation of their hunting habits. A new approach, however, to a solution of the study would be a knowledge of the life-history of their prey. If we knew the habits and habitat of all the spiders here recorded, we should at least know into what strange worlds the wasp goes in pursuit of them. For instance the mother in nest 55B showed such a fondness for *Gayenna pectorosa;* where does she go abroad to find this spider? Comstock[6] tells us absolutely nothing but gives a taxonomic description. Not only is there no word about the habits of the genus, but even in the discussion of the subfamily, *Anyphaeminae,* to which this genus belongs, there are no generalities which even hint at the probable habitat. The Cambridge Natural History, (the volume on spiders by Warburton) has not even the name in the index. It takes very little of this sort of examination to make us humbly admit that little *T. clavatum* knows more about some spiders than do her human brethren. This wasp-mother also collected two specimens of *Philodromus pernix.* Of this species Comstock tells us that it is the most common representative of the genus, found on houses and fences; it is gray, resembling in color old unpainted buildings. When we seek information concerning *Epeira sp.* and *E. parvula* which she gathered, we find under the name of *Eustala anastera,* in the Spider Book, that they are frequently exceedingly self-protective, resembling the bark of the tree or other plant on which they rest, and they act as if conscious of this protection, running only a short distance and then crouching

[6] Spider Book, p. 512.

down close to the bark. The webs are made in low bushes and are vertical. Of the third species which this mother took, the same author says that the species is widely distributed and common in many places; it is usually found under bark or stones. From this we can only see that this wasp goes out among the vegetation for her prey, and furthermore she gets those which are protectively colored.

The second *T. clavatum* also was forced to visit various habitats in the garden to get her prey. *Synema parvula* is frequently found on the blossoms of umbelliferous plants (Comstock, p. 541); members of the genus *Phidippus* are usually found under sticks and stones. Of the two species of *Dendryphantes,* Comstock tells us nothing, except that they are nearly related to *Phidippus;* of *Dictyna,* he says that different species show marked differences in habit; one of them usually builds its webs on the walls of buildings, one in the heads of plants, and one on the surface of leaves. The members of the genus *Misumena* are the crab spiders, and inhabit flowers. So the hunting-ground for this mother was the wide out-of-doors.

The third wasp with her 36 spiders covered a large field, in so far as species were concerned. *Oxyopes salticus* is found in early summer running on low bushes; *Epeira foliata* (under the name of *Aranea frondosa,* Comstock, p. 489) makes its web about houses, but more frequently on bushes; the spider is usually found in a retreat near the web; *Dendryphantes* and *Phidippus,* the latter usually found under stones; *Zygoballus bettini* is a common and widely distributed species. Thus so little is known of the habits of the spiders collected by this wasp that we can do little more than guess where or how she found them.

The prey of the fourth individual gives us more information; *Misumessus asperatus* probably has flower-frequenting habits, as has its near relative, *Misumena; Dolmedes idoneus* is a member of the genus of which Comstock says, they are most often observed near water or in marshy places, but sometimes they are found in cellars or other dark and dry situations. Of *Dendryphantes militaris,* we know nothing excepting that it is a very common species. For the last spider, *Theodina puerpera,* no biological data were found.

From a survey of their prey, one concludes that the most of their hunting is out amid the vegetation and occasionally on bark. None of the turret-building or ground-inhabiting or house-frequenting spiders are among the prey.

Four times I have taken nests of *Polistes pallipes,* and found the empty cells used by *T. clavatum* and resealed with mud (fig. 56). During the past few years I have examined hundreds of nests of paper wasps, and have found only these four cases, and all in the same frame building. Here, too, in closing the nest an air-space was made similar to those shown in fig. 55. This fondness of *T. clavatum* for the nests of *Polistes* seems to be of a strictly local character since I have nowhere else found the paper nests reused by this wasp. The fig. 56 shows 19 cells plugged with mud by *T. clavatum,* and the arrows point to 3 cells used by the bee *Osmia cordata* and sealed with a waxy substance. Since we find certain idiosyncracies of a local character, may not the law of heredity after all be a factor in perpetuating new habits?

Trypoxylon albopilosum Fox. [S. A. Rohwer].

Although the clay bank was studied frequently during the early summer, no members of this species were seen about the place until July 7. Since the Peckhams had already described these wasps as nesting in old holes in a post, as soon as I saw them going from hole to hole I at once suspected that they were foraging for spiders in the old bee burrows and carrying their booty away to their nests elsewhere. After some days, however, it became evident that they were actually nesting in the abandoned bee-burrows. Then I realized that I had erred in thinking that they had come from elsewhere to forage here; they had in all probability emerged from nests near by and similar to those which they were making. By July 30th, several females were at work clearing out the old burrows for nests and bringing provisions.

While the heavy work of nest-making and hunting falls to the female, yet the male renders some service in spending his time at home and probably warding off intruders. As the Peckhams[7] have so prettily described, the male keeps watch at the doorway of the burrow; when the female returns to the nest with a spider, he flies out to make way for her, and then as she goes in alights on her back and enters with her. I have further observed that this trick is more than a bit of indolence or pretty play; I have on several occasions clearly seen that mating actually occurs during this short period—not always, but frequently. Nor is the male always the sole aggressor in this unique bit of flirtation. In one nest in particular which I watched while the mother went a-hunting the male deserted his post in the mouth of the burrow and wandered about on the outside a few inches from the hole. The returning female, not being greeted by the physiognomy of her spouse as she neared her doorway, hovered about the aperture for a few seconds until she spied him, whereupon she stopped short and

[7] *Psyche* 7: 303-306. 1895.

rested at the opening with most of her body protruding, until the male could hurry down and join her, when mating occurred as both went inside. The behavior of the female was certainly a most deliberate case of deportment. Had she followed and chased him, or had she ignored him and carried in her spider, one could have called it blind instinct; but the fact that she looked him up and then paused and waited for him almost classifies the deed among deliberate acts.

The Peckhams tell us that the male in charge will chase away other males that attempt to enter the nest, but never objects to strange females entering, and that the females have no scruples against admitting strange males paying a visit to the burrow. I can go the Peckhams one better, with the story of a flying couple that eluded both of their respective partners and mated on the bank very near to the hole where the rightful husband was on watch, and even came unhesitatingly into his presence. When the female had gone into the nest and the resident male was again stationed in the doorway, the impostor still lingered for a few moments dancing and hovering before his very eyes without eliciting from him the slightest response. There again we find individual digression from the customary path of behavior.

Most of the *T. albopilosum* occupied horizontal bee burrows in the face of the bank, One, however, had a vertical nest on the flat top of the bank. She was actively clearing out the abandoned nest of *Entechnia taurea,* and was actually carrying out in her jaws large clods of dirt which had fallen into this vertical burrow. I could not tell whether she was enlarging the hole by biting out lumps, or only removing the loose pieces. She would go down into the hole head-first and back out with a pellet, sometimes depositing it near the hole, sometimes awkwardly flying backwards for a few inches and depositing it; or again, she would attempt this with an exceptionally large clod and awkwardly tumble over. She had no set form for doing things, but seemed satisfied merely to know that they were done. Once her awkwardness in attempting to rise on the wing with a load caused three large pellets to roll down into the hole from the margin; each of these she carried out again and dropped some distance away. There was no male near, nor had I seen one, although I had been watching for him for two hours. She would often fly away and stay for long intervals, but when she returned she continued her excavating. Sometimes I found the suspicion creeping into my mind that these journeys might be of the nature of a hunt for a husband.

When she had been at this arduous work for almost four hours, a male suddenly appeared hovering over her, and just as suddenly and unexpectedly did I see her quit her work and make a quick attempt to preen her body. But she was not quick enough to doff her house-cleaning garb of dusty gray, for already the male was upon her and mating very prettily occurred, lasting almost a minute. Then the female went into the hole and was followed by the male; soon after, he came out and she followed; then he went in again with her after him. Finally they both came out and hovered coquettishly about each other for perhaps three minutes in a sort of nuptial dance, after which she went back to resume her work while he continued his lazy flight a few feet away for about ten minutes. Then he visited her once more and entered the cell; when he came out again both had some antennal communications; then he took his departure while she resumed her work of home-making in earnest. I could stay no longer, and I never learned whether he proved true or false to his bride of twenty minutes.

Subsequently I saw another nest, the home of a pair of *T. albopilosum* where the male remained on guard while the female went to and fro bringing in spiders and mud for wall-making.

The Peckhams find that this species brings in spiders, usually of the *Epeiridae,* and that the specimens are often so heavy that "they are carried with difficulty," and a pretty demonstration of the modifiability of instinct is seen by "the wasp alighting and dragging the spider into the hole instead of flying directly in as usual." In one nest where five spiders were examined two hours after they had been stored two were dead and three alive; in another instance, out of seven spiders four were alive and three dead. In one unfinished cell which I examined, all six spiders were limp and motionless. Two were *Epeira insularis* [J. H. Emerton] and four were immature *Epeira* sp. [J. H. Emerton]. This shows that very often the sting of the wasp is so severe or the spider so weak that they cannot withstand it. What effect the dead prey has upon the feeding larva is not known.

The Peckhams find *Trypoxylon albopilosum* and *T. rubrocinctum,* occupying the holes in one post of their cottage porch. In the clay bank I find *T. albopilosum* and *T. clavatum* using the old burrows of the bees.

According to the same authorities, a wasp can, by working hard, prepare a nest, store it with spiders and seal it up all in one day. In other cases they say the same operation requires three or four days. It takes her from ten to twenty minutes to catch and bring in a spider, but *T. albopilosum* is often absent for a much longer time. Their interest in the nest seems to lag in the second week in August and no new nests were started after August 15th.

The Pipe-Organ Wasp, *Trypoxylon politum* Say.[1]

This creature is a beautiful, shining black wasp with white feet; she is much better known by the illuminating name of *T. albitarsis.* In this species the adults emerge usually in late June[2] after wintering in the larval stage. The prey that the mother catches and stores in the cells with her eggs is spiders of various species, which are usually paralyzed. The nests made by these wasps are long, parallel tubes of mud and are commonly called Pipes of Pan, or pipe-organ nests. Fig. 57 shows the nest as it usually occurs; the short tier is in course of construction. This dainty builder does not daub the cell over with mud, thereby hiding the pretty rings that tell the progress of her work, as does the yellow-legged mud-dauber, *Sceliphron caementarium,* but it, like the latter, smooths the interior of each cell carefully. The holes usually apparent on the upper surface of old nests are made by the emerging adults, and the white spots are the hardened chalky substance which the insects emit from their bodies immediately after they emerge. This white substance is emitted by *Sceliphron caementarium* also, but in the form of many minute pellets discharged before emergence.

The larva of *T. politum* spins a very light web about the walls of its cell (fig. 58X); just inside this it constructs its cocoon, black, very strong and brittle (fig. 58). This it makes of the excrement which it clears from its alimentary tract after it has finished feeding, and utilizes for a cocoon by throwing it all over itself. This is

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[1] Some of the details are from an article by P. and N. Rau in *Journ. Anim. Behavior,* 6:27-63. 1916.

[2] In 1920 I had one nest from which three adults emerged on July 4 and six more between July 8 and 13.

kneaded into shape by dextrous movements of the body; it then hardens and makes a very comfortable abode.[3]

These mud nests are usually built against some flat surface; sometimes the back side is lined with mud, and sometimes the board on which it is plastered serves as a back wall. Here in fig. 59, we have a view of the back of one such nest built without a mud wall, showing cells, partitions, pupal cases, spiders, empty cells and two cells in course of construction. In this nest are three instances of the emerging insect opening its way into an adjoining cell instead of to the outside; if the adult belonging in the latter cell had already emerged, this wasp could leave by its exit, but if not it must certainly die imprisoned, because instinctively the insects can open their way through only one wall.

In contrast to this flat form I have seen about a dozen nests built on hanging corn-husks. Here without a substantial foundation the cells attained a perfectly cylindrical shape, as thick on the back as on the front. They afforded sufficient protection in all respects, however, for they brought forth healthy adults. Another nest was found attached to exposed roots under a bank (fig. 62).

On two occasions I have been able closely to observe the details of the building operations of *T. politum* in progress. One nest that I was so fortunate to discover in course of construction was in an accessible position so one could watch the methods of building. It contained two complete tiers and the third was being added. The wasp returned with a mouthful of mud, but our presence disturbed her and she flew away. Only on her fourth return was she content to settle down to her work without

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[3] I have tried to observe this process by placing organisms about to pupate in vials, but they were unable to work on smooth glass, and they produced only thick ribbons of the black material.

heeding our presence. She would remove the load of mud from her mandibles to her front legs and apply it to the structure in its proper place and then smooth and work it down with her head. Her mud-puddle could not have been far off, for she required only from one to three minutes to make her round trip and bring her load of mortar.

As usual, the male remained in the tube that was being constructed while the female brought the mud and continued the building. The male sometimes poked his head out of the cell to meet or greet his spouse, in a way very similar to the habit we have seen in the smaller species, *T. clavatum*. A long pipe was first constructed (fig. 60). This was then filled for a certain distance with spiders and an egg laid with them and a partition put in, making a cell out of this section of the pipe. This process was repeated until the entire pipe was divided into cells, and then a second tier was made beside it. Since all nests are built vertically, with the openings downward, one wonders what prevents the spiders falling out while the cell is being filled, the egg laid and the mud applied for the partition. I have wondered whether the male did not in some way perform this office. It was soon necessary for me to leave, so I captured the female and took down the nest. We found the male 'way up in the topmost corner of the unfinished tier. The two older tiers were complete in every way, properly partitioned and sealed, and each cell contained spiders and a young wasp.

I have often wondered where the participation of the male in the nesting begins—whether the female starts the nest and the male finds it, or her, and assists, or whether they find each other first and proceed to plan their home. One afternoon I had the good fortune to see a part at least of this performance. At 2:30 my attention was attracted to two large wasps which were behaving coquettishly; they were alternately coming together and separating. Closer inspection revealed that they were a male and a female *T. politum,* the latter with a ball of mud in her mouth. A few inches away was the nest in its very early stages of construction; less than a dozen mouthfuls of mud had been applied to it. From this it is evident that at least the male arrives upon the scene very early in the course of nest-building, if not before its beginning. The nest was twelve inches from the ground, on a board wall. The male remained beside it, and waited to meet and greet his spouse when she returned with building materials, but each time she energetically repulsed him until he flew away. While he was gone she applied several layers of mud in this wise. She always went inside the little canopy, and with her head at the orifice applied her ball of mud in the center and spread it downward on one side; this made half a ring. The next load was applied to the other side and completed the ring. Thus each ball of mud made a section which, when dried, resembled in shape a rib from a chop. The ridges or rings can be clearly seen in fig. 61. The male returned several times to the spot but again departed, sometimes at the energetic suggestion of the female. Whenever he had a chance on these visits, he would creep into the little shelter and wriggle about as if trying to see if it would fit him, and then scuttle off again when he found that it would cover only about half of his body. An excerpt from my notes, giving the details of conduct for a short time, may be of value for comparison.

"At 2:33, female adds ball of mud to nest, repulses attentions of male; 2:35, leaves, absent for half an hour; 3:00, male comes and inspects nest and departs; 3:05, female returns with load of mud, takes just one-half minute to apply it in half ring on right side, and departs; 3:08, male takes his stand an inch below the nest; 3:12, female returns with load and applies it to left side; male waits at her 'elbow' and as she departs he again tries the nest, but poor fellow, he finds it still too small; 3:14, female leaves; 3:15, returns and applies mud; 3:15½, out; 3:16½, in; 3:17, out; 318½, in; 3:19, out; the male meanwhile fussing about." I was then obliged to leave for a time, but this gives an idea of the intense industry of the little female. When I returned at 4 o'clock the nest was an inch long. Soon the male came back from a journey somewhere and went directly into the nest. It was large enough now to completely cover him! Once securely inside, he hummed almost incessantly. He sang while she worked, and she sang at her task, but the sounds were two distinct tones; his note was one continuous, low trill, while hers was intermittent and more loud and shrill. Once inside, he did not again venture out. He eventually ceased buzzing in there, but if one poked him with a straw, he would promptly resume it; he made no sign of flying out or attempting in any way to protect the nest.

The nest, now one inch long, had 24 rings; each ring represented two balls of mud; the little worker had brought and applied 48 loads of mud between 2:30 and 4:30! The male was now happy. She had provided him with a roof; I suppose she will next bring him food and clothes. *Homo sapiens* might question her claim to credit for intelligence in her action, but could his be in closer imitation of the conduct of day-before-yesterday in our race?

A nest of *T. politum* consisting of four tiers or "pipes" showed by the condition and size of the larvae within the cells just which tiers had been constructed first. They had not been made in consecutive order; the second tier had been made to the right of the first, the third to the left of the first, and the fourth to the left of the third; in other words, the tiers in order of their manufacture stood 4, 3, 1, 2. Tiers 1 and 3 had four cells each, 2 had three cells, and 4 was still being filled.

On July 21 I found that the nest begun on June 29 was now a nest of two tiers, complete, and the parent wasps were gone. One tier had five cells and the other one four. At this date all the cells had fully developed pupae, showing that from egg to pupation is less than 23 days in *T. politum.*

The form of *T. politum* nests is sometimes unique. One nest consisted of only one pipe, 20 inches long. The mother, instead of making a series of pipes as usual, seemingly got up her momentum in making one pipe, and never stopped until it had attained this surprising length, and enclosed enough space to make a normal complete nest. This was built into an angle of the woodwork, with a distinct saving of material and labor, and the wasp adapted herself to this convenience. We should like much to know to what extent she was aware of her ingenuity and economy!

The progress of the construction of another nest was watched. It took the wasp three weeks to build two tiers of four inches each. The illustration (fig. 60) shows all that it accomplished from the time it first commenced until August 13, or three weeks. The unusual method of building the second tier before filling and partitioning the first one was here seen. The usual order of business of *T. politum* is to build a tier, bring in spiders, oviposit and build the partition, and repeat this process until the tier is filled; then build a second tier. In the case of this exceptional nest, the male was constantly in attendance, remaining in the latest tube, and always made a terrific buzzing commotion when a straw was inserted. This mother may have been erratic, or she may have been merely keeping her fingers busy while waiting for the maturation of her ova.

The quantity of provender consumed by the young of these various wasps is always a point of interest. We take it for granted that the mother knows and provides just the right amount of food to bring her young to maturity, but we have not investigated the frequency of her fallibility. One larva of *T. politum* had completely exhausted the supply of spiders which had been provided for it, but had not yet made its cocoon. This gave an opportunity to see if a larva would eat more than the usual amount of food provided for it. A large spider was removed from another nest and placed with this larva. Within six hours this had been devoured. Then two other large spiders were placed in the cell, and when the examination was made two days later it was found that the larva had devoured one whole spider and half of the other and was now enclosed in its cocoon. This simple experiment shows that this larva reached the limit of its capacity at two and one-half additional spiders. This over-feeding was not injurious to the insect, because later it transformed into a normal adult. Another individual greedily devoured two and one-fourth additional spiders, and pupated leaving the remainder of the last one in its cell. It also emerged a healthy adult. David Sharp quotes Peckholt who says, in speaking of this species: " . . . however great may be the number of insects placed by the mother wasp in the cell, they are all consumed by the larva, none ever being found in the cells after the perfect insects escape therefrom."

One often finds nests, portions of which, and especially the middle portions, are two, three or even four tiers high, built one on top of the other, as shown in fig. 61, where there were two layers and a third was being built. Whether one mother constructs tier upon tier, or whether a second mother builds her nest on top of the first, I do not know. This condition occurs almost too frequently to be attributed to mere accident. Nevertheless the occurrence of nests in this form brings out an interesting point in the instinct of the emerging wasp. Fabre[4] carried out some experiments with the mason bee, *Chalicodoma muraria,* in which he found that instinctively the insect could bore out of only one earthen covering, and while apparently it had the physical ability to emerge from an extra covering it would rather die in its prison-like house than make the extra exertion to escape. But how fares it with these wasps whose mothers or aunts build tier upon tier, making it necessary for the emerging wasp to bite through more than one wall before gaining its freedom? It is interesting here to note that the insects seem to have some faculty of discerning the front side of their cells, just as the larva of the blue wasp *(Chalybion)* or the yellow-legs *(Sceliphron)* has the faculty of righting itself in its cell as it reaches maturity so that it always pupates with its head toward the exit. In *T. politum* nests of only one layer of cells, one seldom sees an error in choosing the proper side for exit. It has been my good fortune to obtain a few nests which were two or more layers deep, and to study their contents to learn whether these wasps did plod faithfully on until they gained their freedom, or gave up at the first defeat. I have little doubt that there is sufficient strength in those mandibles to penetrate several walls, so the question is

[4] The Mason—Bees. Tr. by A. T. DeMattos. Chap. II.

merely one of instinct. One nest of two layers was placed flat upon a table so that the emerging insects could not gain their freedom by way of the underside, which was partly open; the table merely replaced the board wall upon which it had been built. Fourteen wasps escaped in the normal way from the top layer and the periphery of the lower layer. Seven adults in the central cells could not escape, but each one bored through the wall and entered the adjacent cell, where they were found dead. They followed no special direction in breaking out of these lower cells; one went through the front wall, and the other exits were equally divided on either side. In one such dungeon three such dead prisoners were found, the original inmate of the cell, and the neighbor from either side. Had each one of these seven mature wasps had the instinctive courage or energy to push on through one more wall, all would have escaped. In another nest we found where the same inability had brought death to one insect, the only one in the nest that was so situated that its exit led to another cell. In a third nest the same was true for two wasps. We cannot call this defective instinct, but only very simple instinct, for in the insects' normal experience they should have but one wall to penetrate in order to gain their freedom. One would like to say at least that it is wonderful that the emerging wasp knows how to direct its exit toward the light, but even this is not always the case. I have another record of an eight-celled, one-story nest in which three individuals had bored through the side-wall into their neighbor's cell and died there, instead of breaking through their own roof to freedom. So even this instinct of working out toward the light is sometimes defective.

For a long time there was a scarcity of *T. politum* nests about the much-studied region of Wickes, but at last I found on the supporting timbers of a club-house built on stilts about twenty of these pipe-organ nests. The majority of them were comparatively new, and I remembered that only three years before there had been in this place only two of these nests. Since no others were to be found thereabouts, this is strong evidence that wasps of this species do not wander far from their birthplace to build.

The duration of the pupal stage was, in the only specimen accurately observed, 27 days, July 23 to August 20. A study of the proportion of sexes at the time of emergence shows a predominance of males. Nine small nests of *T. politum* in June, 1913, gave forth 65 adult wasps, of which 41 were males and 24 were females. In some nests the males equaled the females in number, but in no case did they exceed, while the males actually predominated in the majority of nests in this small collection. One wonders if this proportion exists at all times later in the season, and also whether the males continue to predominate in numbers after they are out in the world, or if one sex is eliminated more rapidly by enemies or environmental conditions.

T. politum on the authority of Walsh is cited in McCook's Nature's Craftsmen (p. 216) as a guest wasp not building a nest for itself, but laying its eggs in cells made and provisioned by another species. This *politum* of Walsh should not be confused with the *politum* of the present article, which was formerly *T. albitarsis.*

These wasps, of course, suffer from the ravages of the parasites. I have bred the hymenopterous parasite *Melittobia* from their larvæ, and on several occasions the Mutillid parasite, *Sphaerophthalma scaeva,* has been bred from the cocoons, but here too, like those of this species bred from *Sceliphron* nests, all were males. I found one nest infested by an Ichneumon fly belonging to the tribe *Ophionini.* Birds, also, while they are neither parasites nor inquilines, should be recorded as enemies of *T. politum,* which cause heavy losses. It is a simple matter for a bird to peck through the mud walls of the pipe-organ nests, and we often find evidence of this injury. On one occasion a blue-jay was actually seen breaking into the nest and feasting upon the larvæ therein.

Some old cells of *T. politum* were infested by mites, probably *Pediculodes ventricosus* Newport, but since there was slight mortality in this lot of material I presumed that the mites had come after the emergence of the wasps to feed upon any old spiders which chanced to be there; several individuals of the Tachnid fly, *Sarcomacronychia trypoxylonis,* were reared from these mud cells by C. H. T. Townsend. *Pseudagenia mellipes* makes her own mud nest within the abandoned cells (as shown by arrow in fig. 63). I have also found their abandoned cells used by *T. clavatum;* these did not remove the heavy cocoon, but lined it smoothly with a thin layer of mud. *Pseudagenia adjuncta* also made small mud cells within the old cocoons remaining in the nests, and the bees, *Osmia cordata,* plastered and resealed the old cocoons in the nests with a waxy substance (see fig. 64).

A study of a collection of nests of *T. politum* comprising 1282 cells gave some interesting evidence on the vigor of the species, and some indication of variation or defect in instinct. It was cheering to find that 972 of these, or 76 per cent, gave forth good adults in the spring after wintering in the cells. In 126 cases (10 per cent) the mothers had erred in failing to provision the cell or to oviposit, while an additional 27 cells had been sealed stark empty. In some of the latter cases the sealing partitions were placed so that the cells were so small that a growing larva could not possibly have had room to develop anyway. In four cases death in the larval stage might be attributed to insufficient food, while 20 others died in the larval stage despite the fact that food remained untouched in their cells. The remainder, about 6 per cent, were parasitized by *Melittobia, Anthrenus,* a Dipteron and an Ichneumon.

The species of the prey used by these wasps was determined in only three cells of one nest; the 18 spiders in them all proved to be *Epeira donnciliarum* [J. H. Emerton].

For interesting information on the feeding instincts, responses to light, shadows, hues and brightness, the reader is referred to a paper by Dr. C. H. Turner in the Journal of Animal Behavior, *2:* 353-362. 1912.

Trypoxylon plesium Roh. [S. A. Rohwer].

This *Trypoxylon,*[5] a new species, makes beautiful little nests in hollows in twigs (fig. 65); the yellow cocoons all in a row of soft, neat cells present a scene which is certainly worthy of the name of domestic art. The first I saw was in a sumac stem taken in the edge of St. Louis, April 1, 1920. There was a hollow 3½ inches deep and 5/16 inch in diameter. The nest itself, however, occupied only the upper 2⅛ inches; why the little tenant did not utilize the rest of the tunnel which was all ready for it, I cannot see. There was a mud plug to serve as the floor of the first cell. The bottom cell, built on this, was ¼ inch long, and it contained a dried mass which proved, by the aid of the microscope, to be four fungus-

[5] This species is described from material bred from these twigs by Mr. S. A. Rohwer in Proc. U. S. Nat. Museum *57:* 229, 1920.

covered spiders; no evidence of egg or larva could be found. The next three cells were likewise ¼ inch in length, and contained cocoons of a light yellow color. The young wasp in the top cell was injured in opening the twig. The gallery of approximately ¾ inch led to the orifice of the twig, which in this case was open. The partitions were very thin, 1/32 to 1/16 inch, and were made of mud.

Another stem containing this wasp's dainty nest was taken at Shaw's Garden in January, 1920. It had a tunnel 4½ inches long, which was not straight but fluctuated in even so tiny a space as the pith chamber of a stem ¼ inch in diameter (fig. 66A). The width of the tunnel itself varied from ⅛ to 1/6 inch, and contained 7 cells and 5 yellow, opaque cocoons ¼ inch in length. There were very thin mud partitions between the cells and the pupal cases crowded against them. One cell in the middle was empty, but this contained a small dried mass which proved to be the remnant of a spider with hairy legs. Since it was found in the middle cell, this is sufficient proof that spiders are the prey of this species.

The cocoons were not transparent, so on March 31 I opened one, the lowermost, to ascertain its condition, and found the larva having a slight constriction about the neck, showing that it was then transforming into a pupa. The one second from the top displayed the same condition. I dared not open more, but this indicated a tendency to simultaneous development, perhaps preparatory to simultaneous emergence. Above the topmost larva was an empty space of about an inch; then there was a thin mud partition, and above that a continuation of the open gallery for ¾ inch to the orifice. One adult emerged from this nest on June 16. It is interesting to note that although the constrictions, the first evidence of transformation, were apparent on March 31, the one individual which survived to adulthood did not emerge until much later, June 16. Several others from different twigs, not described here, emerged during the last week in May.

In the third sumac twig harboring this species which was taken for study, the tunnel, 7 inches long, gave every evidence of having been previously used. Although it was so deep and in all readiness, this wasp declined to use more than the customary amount, about 4 inches. At this distance below the top of the stem was a thin mud floor, and above this, crowded into a space of 3¼ inches, were 8 cells containing 8 cocoons of the same light yellow color. An open vestibule occupied the upper inch. The partitions were very delicate and made of mud; they varied in thickness, but the stoutest of them was perhaps 1/16 inch. Seven adults emerged from this series during the last week in May, at the same time that others of this species came forth.

Other nests were so similar that it seems superfluous to record the details. Some of these, however, brought forth parasites, two *Chrysis (Tetrachrysis) sp.* [S. A. Rohwer], and four green parasitic Chalcids of the family *Cleonyidae* [S. A. Rohwer].

Fig. 66B is a nest of this species, and shows the method of preparing a twig for study; strips of mica or cover-glasses are attached with adhesive tape to replace the side of the twig which is cut away.

Trypoxylon texense Sauss. [S. A. Rohwer].

This wasp, red and black with golden pubescence, has been taken by me only once in fifteen years collecting about St. Louis. It is recorded from Texas, California and Mexico by Dalla Torra* and Nebraska by Mickel**, and from Kansas by Hungerford and Williams***. While they were not taken on Missouri soil, they were abundant near by. At last a harvest of mud nests of *Sceliphron caementarium,* gathered from a barn at Fish Lake, Illinois, about ten miles southeast of St. Louis, gave forth large numbers of these wasps. Hartman**** tells us that *T. texense* occupies small crevices in wooden or stone walls, beetle burrows and cells of old mud-daubers' nests. Thus the custom of using mud cells is not new to *T. texense.* When several mud nests were cut open (fig. 68) more than fifty cocoons were counted; in every case but one we found only one cocoon to the cell. The exceptional cell had two cocoons with a thin mud partition between them. When using the old cell, the mother *texense* usually sweeps the debris (spiders' legs and bits of cocoon left by the previous tenant) against the back wall. One can readily see that the cells have been resealed. In many instances we find the same kind of double plug with an air space between that we have recorded for its cousin *T. clavatum.*

They all emerged from the nest between August 1 and 10, and only a very few were parasitized by the chalcid *Mellitobia.*

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*Catalogus Hymenopterorum, 1897.
**Univ. Nebr. Stud., 1917.
***Ent. News 23: 248, 1912.
****Bull. Univ. Tex., No. 65, 1905.

CHAPTER VII.

The Nesting Habits of the Yellow-Legged Mud-Dauber, *Sceliphron caementarium.*

What insect can be mentioned which is so universally known as the common yellow-legged mud-dauber? It occurs in almost all parts of this country; almost every school-child recognizes it as a frequenter of the mud-puddles and every farmer and housewife is familiar with the mud nests plastered on the ceilings of porches, barns or even attics. One would naturally conclude that the last word had been said upon the life-history of so common a creature; perhaps this simple assumption has been one reason for the neglect of it by investigators; at any rate, this astonishing condition exists, that the literature contains less information regarding this near neighbor of ours than it has concerning many far-away and obscure species. To be sure, the Peckhams have given a very interesting account, but since they placed the two species most common in their neighborhood in the same genus, under the names *Pelopoeus cementarius* and *P. caeruleus,* and throughout the fifteen pages of their account of habits they make no distinction in the way of attributing certain habits to one wasp or the other, one cannot tell which species they mean. The confusion is more apparent when one runs across sentences such as this: "Almost invariably she decides to build for herself, although now and then she uses an old nest," or "in favorable weather the blue wasp often builds and stores a nest in a single day." It is easy and natural, when one sees them store and seal a cell, to conclude that of course they made it. While one is very reticent about questioning the statements of such observers as the Peckhams, I must state that in my own long observation of the wasps at work, I have never seen *S. caementarium* use an old cell or *C. caeruleum* build a new one. Now since I have recently discovered how entirely different are the two species in their habits, even those pages will have to be revised. It is natural that these erroneous conclusions should be reached by a study of the nests in the laboratory; this perpetuation of an error is a weighty argument in favor of field observations, for one turn to the nearest barn at almost any point in our country at any time from May to October would have disclosed the truth about this common insect.

The two species, *Chalybion caeruleum* and *Sceliphron caementarium,* formerly placed under the generic name *Pelopoeus* and regarded as two species of the same genus, are said by Rohwer to have certain anatomical characters which undoubtedly place them in two distinct genera.

It is interesting to know that the Peckhams, in opening the nests, found some cells that had been used a second time, and concluded that since both species emerged from them, both species make new nests and that both species likewise sometimes use old nests. Close observation, both in the field and in the laboratory, has convinced me that wherever the cocoons* are those of *Chalybion* the plug shows that the nest has been resealed, and that where the occupant is a young *Sceliphron* the entire nest is new and the plug at the opening is still the original one.

The Peckhams point to the fact that often the builder finishes the nest by sticking numerous round pellets over

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*In a former paper I have shown that while the cocoon of *C. caeruleum* is similar to that of *S. caementarium*, it has in addition a white, webby silk cover which the former lacks. In ten years, I have never found this distinction to fail.

the outside of the sealed nest, forming a conspicuous but fragile decoration (fig. 67), instead of the more customary method of spreading the last loads of mud over the outside of the nest, thus making an excellent reinforcement for the finished nest. Since this occurs so infrequently (in my count about one in every twenty or so were decorated), I suspected that this was done by *Chalybion* and not by *Sceliphron,* although from the Peckhams' account it would seem that in both species some mothers are so artistically endowed. The majority of these decorated nests were *Sceliphron,* and in the few cases where they proved to be *Chalybion* the usual evidence was present to indicate that the cells had been gnawed open and replugged, and hence were being used for the second time. So we may safely conclude that the decorations are put on by *Sceliphron* and that these nests may later be used by *Chalybion* the same as other nests.

The same authors state that they found 546 nests out of 573 with the openings on top, with the longitudinal axis nearly vertical, while only 27 were built in a horizontal position with the opening at the side. While I have not actually counted the nests in these two positions, I do find that in the St. Louis region the opposite occurs. This, however, and the cause thereof, will bear further investigation.

The direct statement, "In favorable weather the wasp often builds and stores a nest in a single day," is absolutely contrary to anything I have seen in nest-building by *C. caeruleum.* In fact, this point first led me to suspect that *C. caeruleum* follows parasitic habits. For years I have seen both species at mud-puddles; there *S. caementarium* buries her head deep in the soft mud a few inches from the water's edge and often even stands on her head the better to bite out a chunk of mud to carry to her nest, while the blue wasp, gently coming to the water's very edge, takes long draughts and departs, but avoids the mud. Now I find that the latter species is a carrier of water by the aid of which she breaks into the nest of the former species.

The next item of discussion, the position in the cell of the spider upon which the egg has been laid, deserves the full quotation: "Our wasps did not share the habit of those observed in France in laying the egg on the first spider placed in the cell. Indeed, we found that it was only after the nest was completely provisioned that the egg was laid on the abdomen of one of the last brought in. The importance which Fabre attaches to the early laying of the egg seems to us a little exaggerated, as the difference in time, in the two methods of procedure, cannot be enough to give much advantage either way." As for our American wasps, the Peckhams are both right and wrong, for *S. caementarium*, like Fabre's wasps, always deposit the egg on the first spider brought into the cell, and *C. caeruleum* always lays the egg on the last one.

This distinction seems absurdly insignificant now, but wait. When large numbers of nests are studied in the laboratory, only a few can be found which are in condition to throw light on this subject. Usually one finds, upon breaking open the nests, that the young are either grown larvæ or pupæ, so one cannot tell just what the position of the egg was, but a few are found with the egg or small larva at one end of the cell to indicate where it was born. Within this selected lot of material it is then necessary to determine which is the back and which the front of the cell—a matter which is not so simple as it might appear when the nest is sealed and well daubed on the outside. Foremost, one must carefully consider whether or not the opening has been resealed. The Peckhams opened some cells (number not stated) and found the egg deposited on a spider which had been brought in just before the cell was sealed; this led them to say that it was "only after the nest was completely provisioned that the egg was laid." There they made the error of not knowing that when they found the egg on a spider near the doorway, it was the egg of the cow-bird-wasp, *C. caeruleum,* and not that of the original builder of the nest.

Carefully studying the cell to see which was the back and scrutinizing the closure to see whether the nest had been resealed by *Chalybion* (it is easy when one knows how), I have concluded, after long investigation, that *S. caementarium* always lays the egg on the first spider brought in, and that *C. caeruleum* always deposits its egg on the last one. The fact that *Sceliphron* deposits her egg on the first spider has a direct bearing on (a), the nesting behavior of *C. caeruleum,* and (b), the work done to test for the American wasps the experiments carried on by Fabre on the French *Pelopoeus.*

For the first part, I have concluded that *Chalybion,* once a mud-nest builder, has so far changed her habits that now she is a water carrier; that instead of carrying mud to build her house she carries water in her gullet wherewith to soften the walls of another wasp's nest so she can enter it, house-breaker fashion, and then carries out the spiders placed there by the rightful owner and brings in her own. Since the provisions of both wasps are the same, a general mixture of various kinds of spiders, one wonders how long it will be before *C. caeruleum,* already versatile and shrewd enough to be a house-breaker, will also learn to know that spiders are spiders, and all are good food, whether of her own choosing or not. How long will it be before she learns to retain the spiders and save herself the trouble of gathering a new lot, and thereby gradually acquire habits that are more or less parasitic? It is indeed puzzling that she has not already learned it, since she has proved herself ingenious in adopting other labor-saving devices.

When we again ask ourselves why, we find the question unanswerable until we consider just what the position of the egg of her predecessor is. When we know that *S. caementarium* lays her egg on the *first* spider that she brings in, then it dawns upon us that there is good reason for *C. caeruleum* to carry out and throw away every spider to the very lowermost one in the cell, since only by that means can she be sure of eliminating her enemy's egg on the last one. Rather would she destroy perfectly good food, and labor to replace it with the same kind, than risk her egg in competition with the young of the original owner. In this she is wise—or at least she acts wisely—because if the *Sceliphron* egg were allowed to remain in the cell the larva therefrom would not only be present in the cell, but would always be a little the older and larger of the two, and hence would win in the majority of cases on the fateful day when it was decided which should eat the other.* Thus we see that while it makes very little difference to *Sceliphron* where her egg reposes, it does make a vast difference to *Chalybion,* and the latter has regulated her habits to conform in astonishing detail to the ways of the first.

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*For an account of the cuckoo-bird habits of *C. caeruleum,* see article in Ann. Ent. Soc. Amer. March, 1928.

The second problem, the position of the egg in the nest of *S. caementarium,* and the experiments made to test Fabre's work with the mud-dauber of France, is given in the following pages.

The Prey of *Sceliphron Caementarium.*

After reading Fabre's account of the nest-building of the French mud-dauber and his experiments in trying to mislead its instincts, one is left with a feeling that these creatures are bundles of stupidity. This is what happens, to quote Fabre's words:*

"A cell has recently been completed. The huntress arrives with the first spider. She stores it away and at once fastens her egg upon the spider's belly. She sets out on a second trip. I take advantage of her absence to remove with my tweezers from the bottom of the cell the head of game and the egg. What will the insect do on its return, confronted with the empty cell, this cell no longer containing the egg, the sole object of her industry as a potter and her skill as a huntress?

"The disappearance of the egg must be obvious to the wasp who has been robbed of it, if her poor intelligence possesses so much as the rudimentary gleam that enables us to distinguish between a thing's presence and its absence. The egg, were it alone, . . . might escape the mother's vigilance; but it lies upon a comparatively bulky spider, of whose presence the *Pelopoeus,*** on returning to the nest, is undoubtedly apprised of by the sense of touch and sight when she deposits the second victim beside the first. Once more, what will the *Pelopoeus* do when confronted with her cell, where the ab-

*The Mason Wasps, p. 109, 1919.

**Fabre uses the generic name *Pelopoeus,* which is synonymous with *Sceliphron.*

sence of the egg henceforth renders the bringing of provisions useless and absurd?

"What she does is to bring a second spider whom she stores away with the same cheerful zeal as though nothing untoward had occurred; she brings a third, a fourth and others still, each of whom I remove during her absence, so that every time she returns from the chase the warehouse is found empty. For two days the *Pelopoeus'* obstinacy in seeking to fill the insatiable jar persisted; for two days my patience in emptying the pot as she stocked it was equally unflagging. With the twentieth victim, persuaded, perhaps, by the fatigue of expeditions repeated beyond all measure, the huntress considered that the game bag was sufficiently supplied and she began most conscientiously to close the cell which contained nothing.

" . . . I have suggested that the insect's rudimentary intelligence has practically the same limitations everywhere. The accidental difficulty which one insect is powerless to overcome, in default of a gleam of judgment, any other, no matter what its genus or species, will be equally unable to overcome."

In order to test this work, we made similar experiments on the American mud-daubers, *Sceliphron caementarium*. Experiments 1 to 19,*** made a few years ago, lend much to the substantiation of the later ones, 20 to 27, which were made after reading Fabre's account and were made directly to test this point. It is fortunate that these experiments, especially the earlier ones, were recorded in sufficient detail to show at least that our American mud-dauber is something just a little in advance of bundles of stupidity or vehicles of instinct.

***Journ. Animal Behav. 5:240-248. 1915.

Fabre reaches these sweeping conclusions from experiments upon one insect. How does he know that the wasp "judged the nest was sufficiently filled, and conscientiously" closed it containing nothing at all? The following data will show that when a larger number are studied it is evident that a great deal of individuality is manifested in the behavior of these mothers. In a multitude of witnesses there is strength; it is unfortunate that Fabre did not make tests on a larger number of his wasps. I believe that stupidity exists among wasps, and perhaps Fabre was unfortunate in catching one that required twenty trials before she learned the futility of her labor. Had he experimented on a larger number, we might have been able to draw valuable comparisons of the habits of similar insects on the two sides of the Atlantic. In the light of our present knowledge, however, my contention is that it was not a question of instinct that caused this creature to bring in mud when she thought the nest was sufficiently filled, but that with twenty trials the wasp at last discovered the futility of her work, was alarmed and dissatisfied with this cell because it was disturbed or somehow "hoodooed" and sealed it perhaps in a feeble effort to shut out the mysterious intruder. As the reader reflects over the experiments, he will probably conclude that possibly the French mud-daubers are not so stupid as Fabre would have us believe, and likewise perhaps the American mud-dauber is not wholly the last word in wasp wisdom.

Experiments.

Exp. I. A new *Sceliphron caementarium* cell was found already one-fourth filled with spiders. When an opportunity occurred, I slyly filled it high with spiders from another nest. The mother wasp returned with a large spider, and spent some time in laboriously cramming it in. Quite satisfied now with her store, she brought balls of mud and duly closed up the cell. While she was gone for another load, I picked open the cell and extracted a part of the contents. Arriving at the nest with the next pellet of mud to reinforce the closure, she saw the injury and at once took alarm, hurried out and threw away the mud, returned and with clearly expressed indignation carried out the remaining spiders one by one, her own as well as mine, until the nest was stark empty, and departed.

Exp. II. While another *S. caementarium* was gone from home, I stirred up the spiders which she had placed in her cell and added one from another nest. When she returned, she promptly carried it out and made four more trips, each time carrying out a spider of her own capture, until all were gone. Then after a brief, unexplained absence she came back and inspected the empty cell, fretted about and examined and stood guard over it for an hour and a half, all because a few spiders had been disturbed.

Upon returning three hours later, I found the cell sealed. I opened it and found just two medium-sized spiders, with an egg attached to one. Thus this mother was so anxious about her progeny that she carried out and rejected all the spiders which had been touched by human hands or forceps, and now she sealed up the egg with only sufficient food to carry it half through its larval life.

Exp. III. One day while collecting nests I removed a large one from a shelf against the barn wall. No sooner done than a blue wasp, *Chalybion caeruleum*, returned to it. She examined the spot very carefully for about thirty minutes. When at last she flew out, I replaced the nest, but before doing so I removed five spiders from the cell which she was engaged in filling. She returned, still with the green spider which she carried when first she found her nest gone. She came back and hovered about on the nest very nervously for some minutes and entered the cell five or six times, seeming greatly excited and puzzled; she re-examined the whole nest again and again and re-entered the cell many times, and finally after thus hesitating for about forty minutes she soared away with an indignant buzz without even depositing her new prey.

While she was gone I removed six spiders from another cell of her own nest (this cell was at the back of the nest, against the wall, so one side was open, but when the nest was returned to its position against the wall, no mutilation was apparent to confuse the owner) and placed them in the new cell. She returned and set about promptly to remove these six spiders, which were probably her own, and either dropped them one by one after a flight of a few inches from the nest or carried them quite outside the barn.

Apparently she had had enough of this cell, for after a few minutes she flew in with a pellet of mud and sealed it up, stark empty.

Exp. IV. A *Sceliphron* mother was busily engaged in stocking her new cell. I plundered the nest of a mud wasp near by and placed six spiders from it in the new cell. The owner returned with a spider of her own, placed it in the cell on top of the stolen booty, pushed the whole in with her head and rammed it down about six times as though it were all her own, then flew out, returning almost at once with a pellet of mud with which she sealed the cell, and reinforced it with five more such balls. All this she did with an air of peace and satisfaction in work well done.

If some wasps can by some sense detect the spiders which have been caught and paralyzed by another of their kind, and express such resentment toward their presence, how much more strange it is that this one seemed not to be aware that part of her prey had been handled by another wasp, besides myself, or if she did know it, cared not a whit.

Exp. V. Next I tried a new form of interference, placing three spiders in a *Sceliphron* cell which was only in course of construction, being but one-fourth completed. So it was not at all surprising that the wasp, after a little commotion, promptly emptied this and proceeded with her masonry.

Exp. VI. A wasp had completed her cell and placed her first spider there. I removed it, filled the entire cell with spiders from other nests and replaced her own spider in the front of the cell so she would see only her own prey when she returned. However, in handling the contents, I broke out a small piece of the wall at the opening. When I returned in a half-hour, I found that the cell had been emptied and deserted by the mother. Why did she go to the trouble of emptying it if she meant only to desert it?

Exp. VII. A new *Sceliphron* nest appeared complete, but was still empty. The insect brought a load of mud, but used it to reinforce the nest, then went all the way into the empty cell and remained there for four minutes, only her tarsi protruding. What may have been her business during that performance, I could not determine. When she was gone, thirteen spiders (one with a small egg attached) from another nest were placed in the cell. Upon the second and third trips also she walked over her nest and deposited the mud on the outside to reinforce it; she did not enter the cell, and I did not see her even look inside, but when she again came she used the load of mud to close the cell, then another and another until the seal was firm, just as though all were normal. Whether she detected the ample supply of spiders and closed the cell on that account, or whether she would have sealed it empty, had I not filled it for her, I could not determine.

Exp. VIII. A mud-dauber's cell was finished and quite ready for use, but the larder was not yet stocked, so I filled it with provisions borrowed from another nest. The mother wasp returned with a fresh spider, started to enter the nest but retreated and flew out of the window, taking her burden with her. She returned empty-handed and carried out the substitutes one by one. After the cell had been empty for a half-hour, I again placed eleven spiders in it. The next morning when I arrived to examine this cell I found it had again been emptied.

Exp. IX. A *Sceliphron* mother was carrying in spiders to fill the twelfth cell of a handsome nest, but had not gone far with the work when I added fourteen from the nest of another of the same species. The wasp returned and at once emptied the cell of my spiders and her own as well, quietly stood guard over the cell for a quarter of an hour with an air of indecision, and then flew away and was not seen again.

Exp. X. A one-celled *Sceliphron* nest was built under a piece of bark on a log beam in the old barn. I carefully removed this bark, filled the cell with borrowed spiders and replaced it so it looked, to my eye, exactly as it had before. When the wasp returned, she had great difficulty in finding the nest. After locating it, she paused only a moment and dashed away, and, returning a moment later, removed these spiders. Since the meddling here had been more extensive than usual, I was not surprised that she resented the intrusion, but I cannot understand what caused her great confusion in finding the nest when the alterations in the surroundings were imperceptible to me.

Exp. XI. A solitary cell contained five spiders when I added six more from another nest. The wasp returned empty-handed, put her head into the cell and worked energetically for three minutes, either inspecting or packing them together or laying her egg. Out she came at last and dashed away, but without a spider; almost immediately she returned with her plaster and sealed up the cell.

When she had gone, I broke the seal and removed part of the spiders which she and I had together supplied. She soon returned with another pellet of mud to add to the seal, but when she found it broken she alertly poked her head in, hastily withdrew and flew away with the mud. After that she made four trips from the nest, each time carrying out a spider which I had failed to remove, but these four were those which she herself had put in. Then for ten minutes she thoroughly examined the inside and outside of the cell, going in and out many times, apparently in an earnest attempt to discover the cause of the mysterious trouble. When I returned that afternoon, I found her again filling this cell with spiders.

During her absence I again meddled, this time inserting twelve spiders from another nest. Returning, she brought a spider which she crammed in on top of the others, and departed. After ten minutes, however, she came buzzing back as if possessed of a new idea, and began to empty the cell! First she took out her own fine fresh one and threw it away, and continued until the cell was again empty. She then remained on the nest holding watch for thirty minutes, as if resolutely waiting to catch the hoodoo. When she left, I expected her to refill the nest with spiders of her own capture, but instead she brought a load of mud and, to my amazement, spread it in a thin layer on the inside of the cell, as though the very walls were polluted, or else all of the trouble were due to its inadequacy. So, for the first time, I saw a wasp adding mud to the inside walls of a cell after she had once deemed it finished.

The next day at 3 p. m. she was still coming to the cell occasionally with an air of angry suspicion and uncertainty, but otherwise it was in the same empty condition that I had left it. Unfortunately, I was obliged to leave on the evening train, so I never knew what she finally decided to do.

Exp. XII. At six o'clock one August evening I filled a new one-celled *Sceliphron* nest with spiders from another nest during the absence of its owner. I was called away and could not observe it further until the next day, when I found the cell sealed. I opened it and found that my substitutes were gone and in their stead were two other spiders. The mother had evidently begun to fill the cell after having thrown out my spiders, but had stopped with only two and sealed the cell without having even deposited her egg.

Exp. XIII. A certain nest of a mud-dauber was almost complete when I filled it with spiders from another nest. The proprietress returned with a load of mud to add another ring. When she saw the spiders she withdrew her head with a start, as though greatly shocked. Again she inquiringly put in her head, with like result. She then went away in bewilderment and returned six times, but each time sought the nest at a spot two feet distant. Sometimes she would walk toward the nest, but always with the manner of one seeking for something lost.

After three days the cell was still in the same condition as I had left it; the wasp never finished it. I think that she firmly believed that her own nest was lost, and that the one which she visited again and again was the nest of another which had been filled with spiders.

Exp. XIV. At 10:20 a new cell, the fifth on this nest, was begun, and in just one hour and a half the new compartment was completed and ready to be filled and sealed. At this point I came forward with unasked aid and placed therein fourteen spiders from another nest. The wasp returned with a load of mud, no doubt to put on the finishing ring, but when she saw the spiders she showed not the least surprise or concern, but proceeded to seal the cell with the pellet she had brought. Then she brought another and another and added them to the closing in the normal manner, showing almost human standards of conduct in being satisfied in doing the thing most convenient at hand which gives the appearance of work well done, and glad of the opportunity easily to forget that she had quite overlooked the principal duty of her life. She seemed to give no serious thought to the presence of the spiders, nor did she make an effort to compress them nor show any concern for depositing her egg. The sight or scent of the spiders seemed to afford sufficient stimulus to cause her to seal the cell. Perhaps the presence of mud already in her mandibles lent strength to the stimulus for this particular action.

At four o'clock that afternoon I found that this industrious mother had made another cell and was finishing off what I thought must be the last ring. When she flew out I placed six spiders in the cell and had not time to insert more when she returned with a load of mud. She got a glimpse of the spiders, which in this case only half filled the cell, and immediately flew out with the pellet. She threw away her mud and came hurrying back, peered into the cell and then bustled out again. She came back to the cell bent on her course of action, dragged out a spider and carried it away. At that juncture I hurried to fill the cell completely by adding ten more spiders. But her zeal for righting wrongs was now aroused, and even this was no inducement to seal it up, for she carried them all out.

Exp. XV. The new cell on this nest was just completed but as yet contained no food supplies, so I placed in it eight fresh spiders taken from another nest. The mother wasp returned with a load of mud and alighted on the nest, but from her behavior I judge that she suspected that it was not hers, for she arose on the wing and flew in circles, as if seeking orientation, and returned. This she did three times, the last time making many smaller circles. Through all of this confused search she carried her pellet. By this time she seemed fully convinced that this was her home, but that something was wrong. So she dropped her ball of mud out at the window, returned in a direct line to the nest and began with a very positive air to carry out the spiders and throw them away, continuing until all were gone.

Exp. XVI. A wasp was discovered putting the first layer on the closure of her cell. I removed this, and also part of the spiders, of her own capture. The wasp came in with more mud, hummed a little in anxious concern and flew out with her load. She returned shortly, however, and again sealed the cell. Again I carefully opened it and inserted other spiders from another nest. She came back and saw the opening, poked her head into it inquiringly and proceeded to plaster it up. For the third time I deftly broke into the cell, but she seemed to be inclined to repair it as long as I would continue to damage it. One wonders if, at any other stage of the work than precisely this, she would have been so inclined.

Exp. XVII. A wasp had packed her cell nicely and already sealed it with two layers of clay. I carefully removed the covering and a part of the spiders. The wasp returned with the next load of mud, hesitated only a little and spread it in its proper place and was off again. Again I opened it and this time inserted four foreign spiders. In due time the mother returned, again plastered the opening as if nothing had happened and departed. Bent upon commanding her attention, I broke the seal for the third time and placed a larva of *Sceliphron* in the doorway, half protruding, so she could not seal the compartment without moving it. But by the time she arrived with her pellet, this larva had worked itself out of the cell, so she spread the mud as usual over the aperture. When she had again gone I tried another very large larva in the same way. The mother wasp returned, made no attempt to remove the larva, in fact displayed no concern for its presence, but spread the mud around it as it lay half protruding from the cell, often severely jarring it as she worked, plastering her mud to the sides of the larva as though it were a part of her wall, and thus again in this silly fashion sealing her cell.

Exp. XVIII. To a *Sceliphron* cell containing a few spiders I added five from another nest. The wasp returned carrying another spider which she crammed into the cell, while with her head she condensed the whole mass. In so doing, she somehow dislodged one and it fell into a spider web below; she alertly recovered it, crammed it into the cell with precision and continued to pack the mass together for about five minutes, then flew out and brought one more spider which she deposited, almost filling the compartment.

When she had again gone I forced five additional spiders into the cell; after a half hour she returned with another capture which she also forced in with great effort. It seemed that she had a fairly definite idea how many spiders were required, and bring them she must and would, regardless of unsolicited aid. This case is in sharp contrast to those which were content to seal their cells as soon as they found them full without asking any questions.

On her next return, however, she brought a load of mud and closed the cell. As soon as she turned her back I opened it and removed one-third of the spiders. Upon her return she paid absolutely no attention to the broken cell or the missing spiders, but used her load of mud to again seal the cell. Once more I removed the seal and this time all of the spiders, in order to impress upon her more forcibly the seriousness of the injury. I accidentally broke a small piece out of the wall of the cell at the opening. The wasp returned, spread her mud over the opening, leaving the broken part untouched and quite ignoring the emptiness of the nest and the traces of vandalism. She discharged her duty always with a mechanical faithfulness; she seemed, nevertheless, exact —three loads of mud are usually required to seal a cell, and three loads she brought and applied properly before finally leaving the nest.

Exp. XIX. When I arrived upon the scene, the fourth cell of a *Sceliphron* nest was half filled with spiders.

Not having other spiders at hand, I placed a pupal case containing a pupa of the same species in her cell so that no part protruded. When I returned two hours later the cell was sealed and a fifth cell was half completed. I had to break open the cell to see if the pupa had been removed. The cell was empty, but the new item of interest was that at six o'clock the next morning I found this damaged cell repaired and the fifth cell still in its half-finished condition. This was the first case in my experience of a wasp going back and giving attention to a previously finished cell after a subsequent one had been begun.

Exp. XX. The mother was filling the cell with spiders; the eight which she had already stored were removed. She returned several times, but brought in no more after she first found that her property had been disturbed, and finally abandoned it.

Exp. XXI. A nest was being provisioned, when all ten spiders were removed at 8:35 a. m. When the wasp found the cell empty, she spent the next five hours in bringing in mud and reinforcing various parts of the nest, and at 3 p. m. she sealed it up empty.

Exp. XXII. The one spider in the cell was removed. At intervals during the day, the mother was seen to carry mud and spread it in various parts of the nest, but in the afternoon she sealed it empty.

Exp. XXIII. At 8:30 a. m. the five spiders were removed from a cell which was then being provisioned, but here too the response of the owner was the same as before, and finally at 1:45 she sealed it empty.

Exp. XXIV. A five-celled mud nest lay flat on the floor. I attempted to remove the spiders from a cell that was being stocked, when the returning wasp caught me in the act. Seeing her spiders disturbed, she removed them one by one, flew high in the air and dropped them to the floor, and departed.

Exp. XXV. At 11 o'clock the spiders were removed from a cell that was being filled. The owner brought in no more after that, but occasionally she fetched a load of mud which she spread over the other portions of the nest, until at 3:45 she sealed this cell empty.

Exp. XXVI. At 7 a. m. the two spiders were removed from a cell that was being stored; up to 2 o'clock the nest remained deserted.

Exp. XXVII. Eight spiders were taken from a cell that was being filled. After that the mother brought in mud from time to time and reinforced various portions of the nest; at noon the cell was sealed, and during the afternoon more plaster was added to the outside.

Conclusions.

When we attempt, finally, to formulate any generalizations concerning the behavior or psychology of these insects, there seems to be only one principle which can be relied upon to hold good in all cases, viz., that the madam will do as she pleases. Cases of similar conduct under homologous circumstances can hardly be found. Yet we cannot regard the behavior of the wasp as indifferent or accidental when we see her very positive air in taking action, and her usual determination and persistence in pursuing it when she has decided upon her course of action.

In most of the cases where the spiders were disturbed the owner was quick to detect it and frequently resented it. But since in her anger she often threw away part or all of her own prey, we cannot determine whether or not she recognized her own or merely regarded with alarm any meddling about her home. Likewise in those cases wherein she accepted the proffered aid she did so with such outward indifference, taking it all as a matter of course after the manner of those accustomed to welcoming charity, that I could not discern whether or not she was the wiser.

In recent years the phrase "chain instincts" has figured largely in the literature of comparative psychology. Very probably some creatures are guided largely by so-called chain instincts, and in reading some of the details in the foregoing pages some may say that this is true of *S. caementarium* also. Bouvier says in speaking of the mason bee: "If she is engaged in building, one can give her in exchange an entirely completed cell filled with food but she will keep on building and adding material to the already completed cell. If she is in the act of collecting food, she does not try to finish an incomplete cell which has been given her, but seeks rather a strange cell in the proper condition in which to store her honey."

It is altogether likely that these creatures are in a considerable degree guided in their sequence of activities by "chain instincts," that type of behavior upon which Fabre bases such sweeping generalities already quoted. I cannot believe, however, that in this group of organisms it is the omnipotent guide that some would have us believe. Individual temperament and a gleam of something more plastic than stubborn instinct sometimes enter in to cause some surprising variations in their conduct; it is a satisfaction to find that in some individuals, perhaps a little more highly endowed, the chain may actually be broken or even reversed.

For instance, in Exp. XI a wasp returning with mud to seal a cell and finding it had been broken into, so far forgot the usual sequence of activity or escaped its impulse that she threw away her mud and cleaned out the spiders that I had tampered with, and, more than that, when I again bothered her cell by placing spiders from other nests in it, she carried them all out and then sat on the nest for thirty minutes in a watchful mein, and finally brought in mud and covered the inside of the cell with several layers, just as though the trouble lay in its inadequacy.

In Exp. XIII, when the mother with an almost completed cell brought in a load of mud for the final ring, found her cell filled with spiders that I had placed there, she withdrew her head with a start as though greatly shocked and then went away in bewilderment; she spent a long time seeking for her nest, often passing her own by as if it belonged to another. Her entire behavior indicated that she did not recognize the nest as her own.

In Exp. XIV, a cell was quickly built and as it neared completion I filled it with fourteen spiders from another nest. When the wasp returned with her mud and saw the spiders, she calmly sealed the cell and then brought more mud to reinforce the plug. This she completed with evident satisfaction, in spite of the fact that the two most vital steps in the work had been omitted. Here we see that "chain instincts," if they exist, sometimes miss a cog; in fact, two—egg-laying and provisioning—have been unconsciously missed here. It seems that in this case the combined impulses created by the sight of the cell full of spiders and the presence of mud in the jaws were more powerful than the urge to oviposition and provisioning. But even this same mother did not respond in the same way when she was confronted with the same situation the next time; when her next cell was finished and I stealthily filled it also, and she returned with her final mud ball, she was so incensed at the sight of the spiders that she threw away her mud and carried them all out.

In Exp. XV, when a mother returned to her new cell and found I had filled it, flew up and repeatedly described circles of orientation before finally discarding her pellet of mud and carrying out the spiders.

The last eight experiments were made expressly to test Fabre's conclusions. One of these, Exp. 22, was the exact counterpart of his (the first spider was removed) and the others very similar (the first few spiders were removed), but not one of these eight wasps reacted as his individual did, and not one tended in the slightest degree to substantiate his sweeping statements that "the accidental difficulty which one insect is powerless to overcome, * * * any other, no matter what its genus or species, will be equally unable to overcome."

EXPLANATION OF PLATE

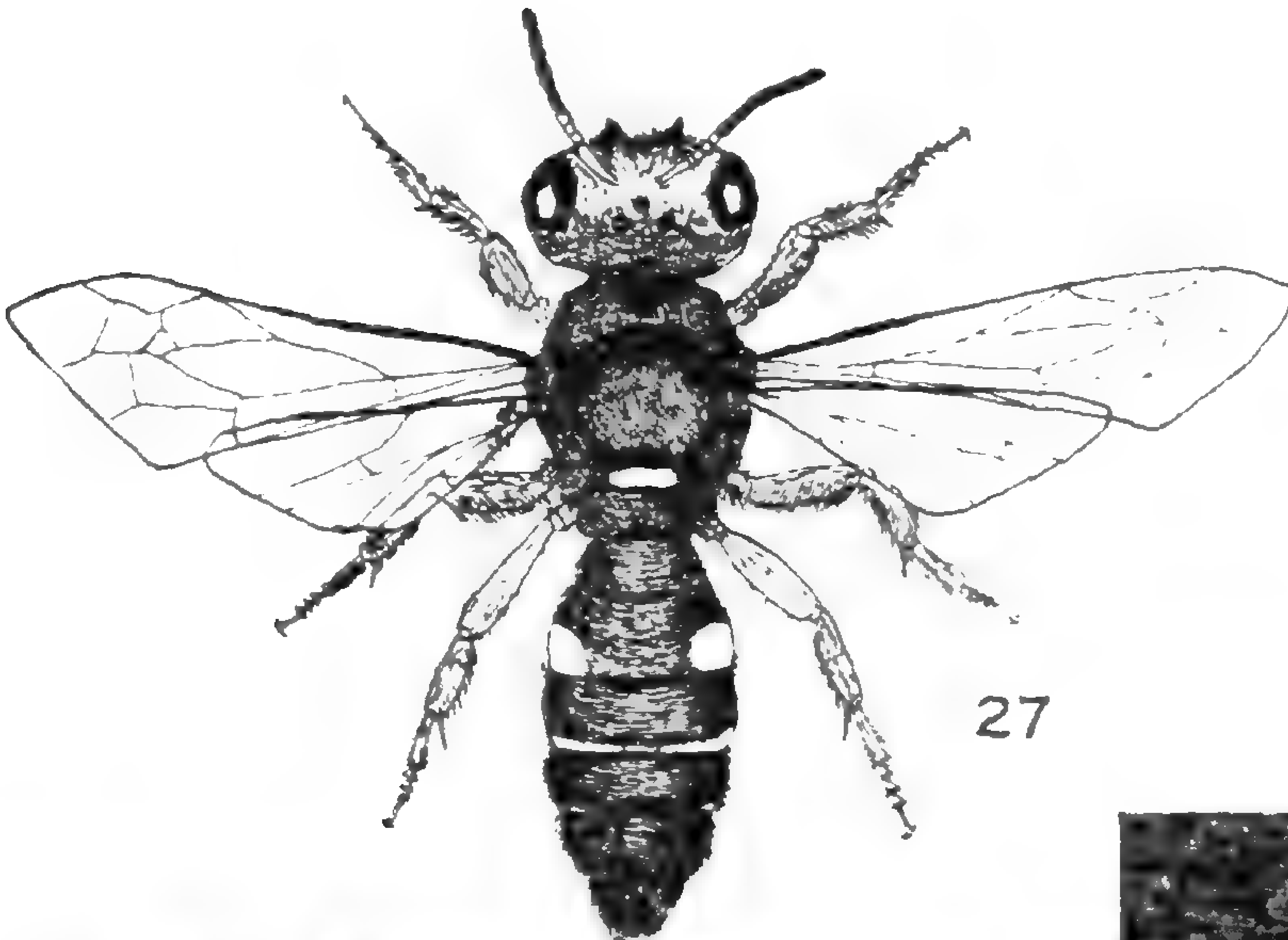
Plate XXII

Fig. 26. Jerseydale, Jefferson Co., Missouri. The road leading up to the milk platform harbored the nests of *Cerceris raui.*

Fig. 27. *Cerceris raui.*

Fig. 28. The nesting site of *Cerceris raui* at Wickes, Mo.

Fig. 29. The opening to the burrow of *Cerceris raui.*



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EXPLANATION OF PLATE

Plate XXIII

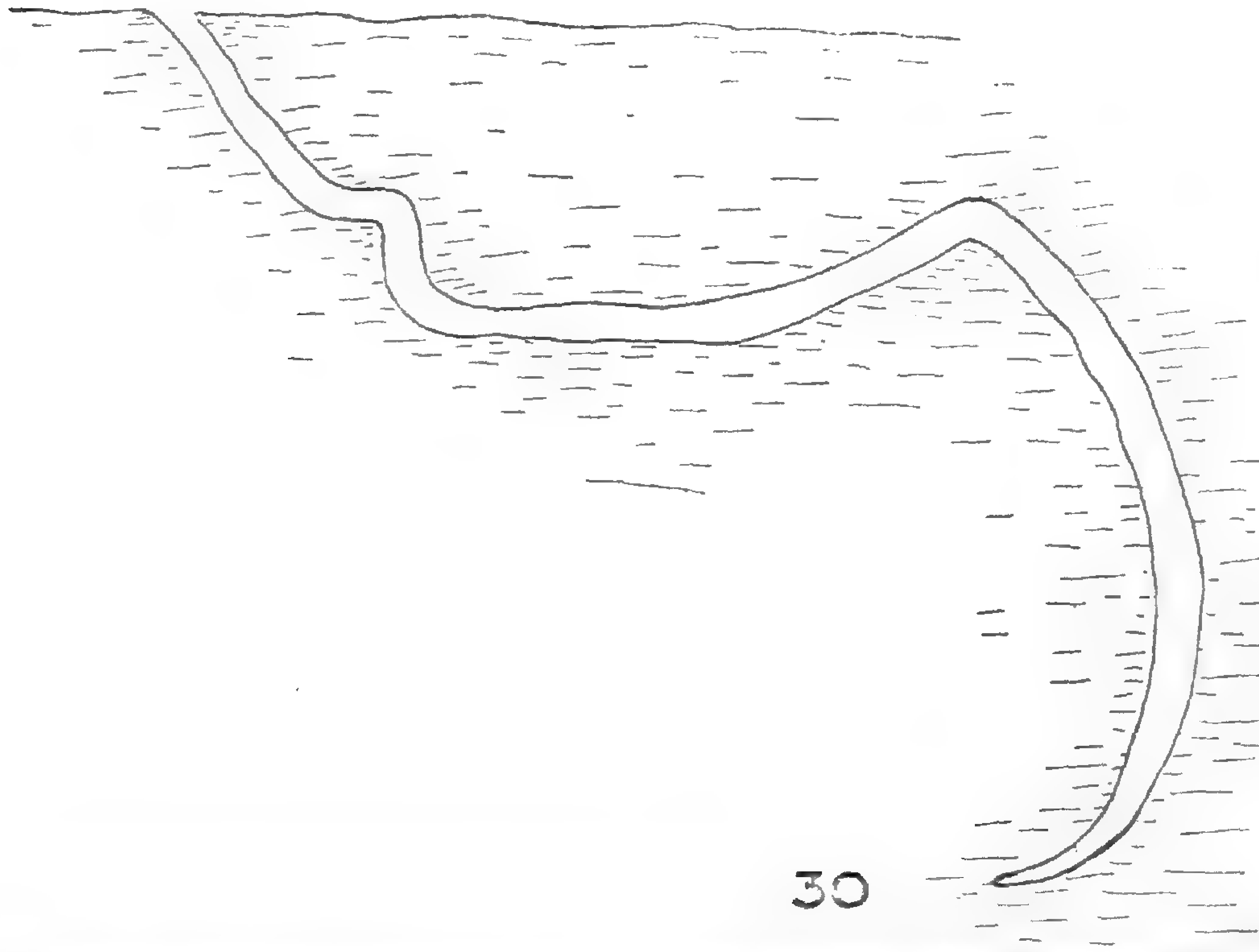
Fig. 30. The tunnel of *Cerceris raui* (one-fourth natural size).

Fig. 31. *Cerceris raui* leaving her burrow.

Fig. 32. The prey of *Cerceris raui; Thecesternus humeralis* and *Lixus concavus.*

Fig. 33. All that remained of the beetles after the feast.

Fig. 34. The cuckoo parasite, *Hedychrum violaceum.*



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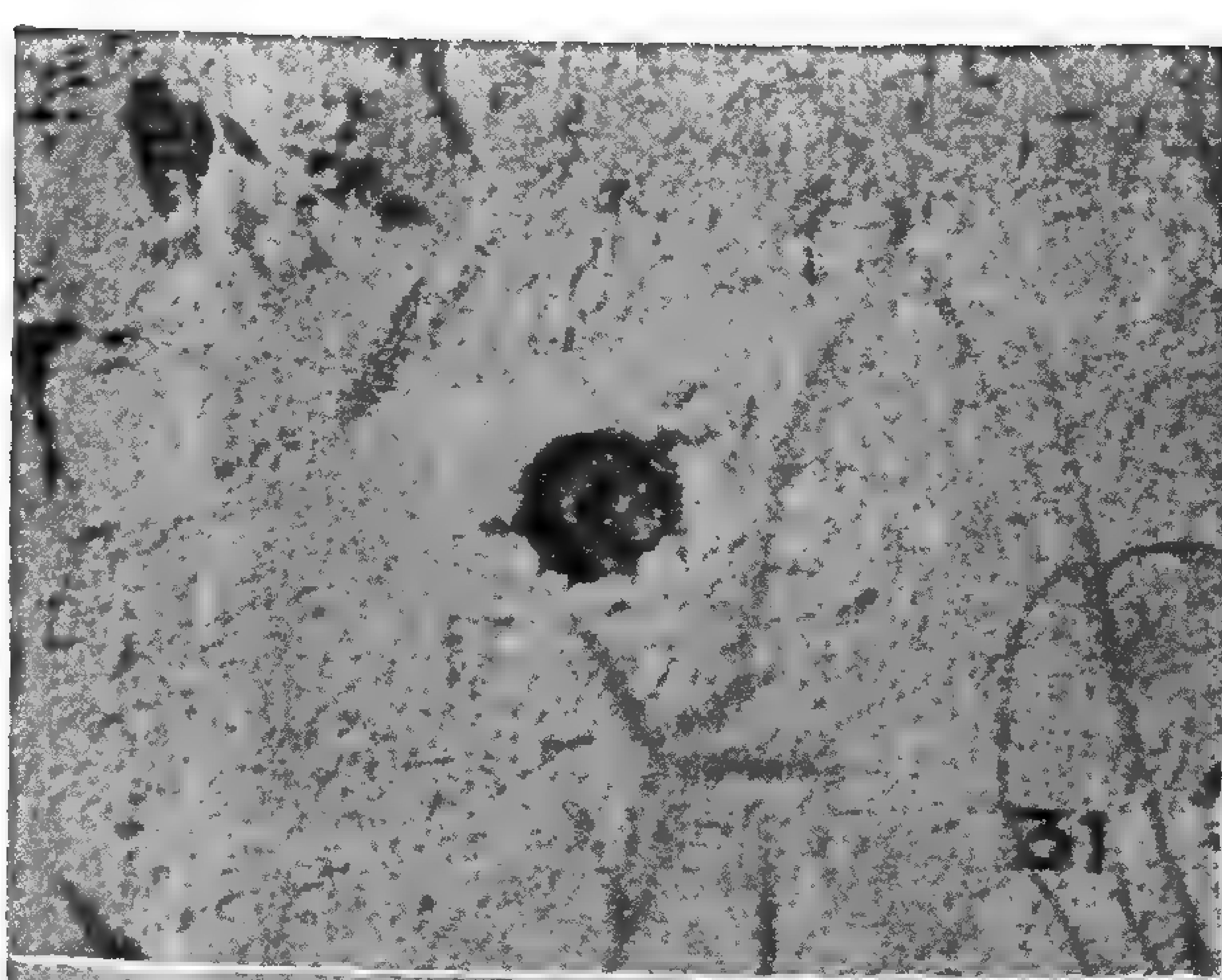

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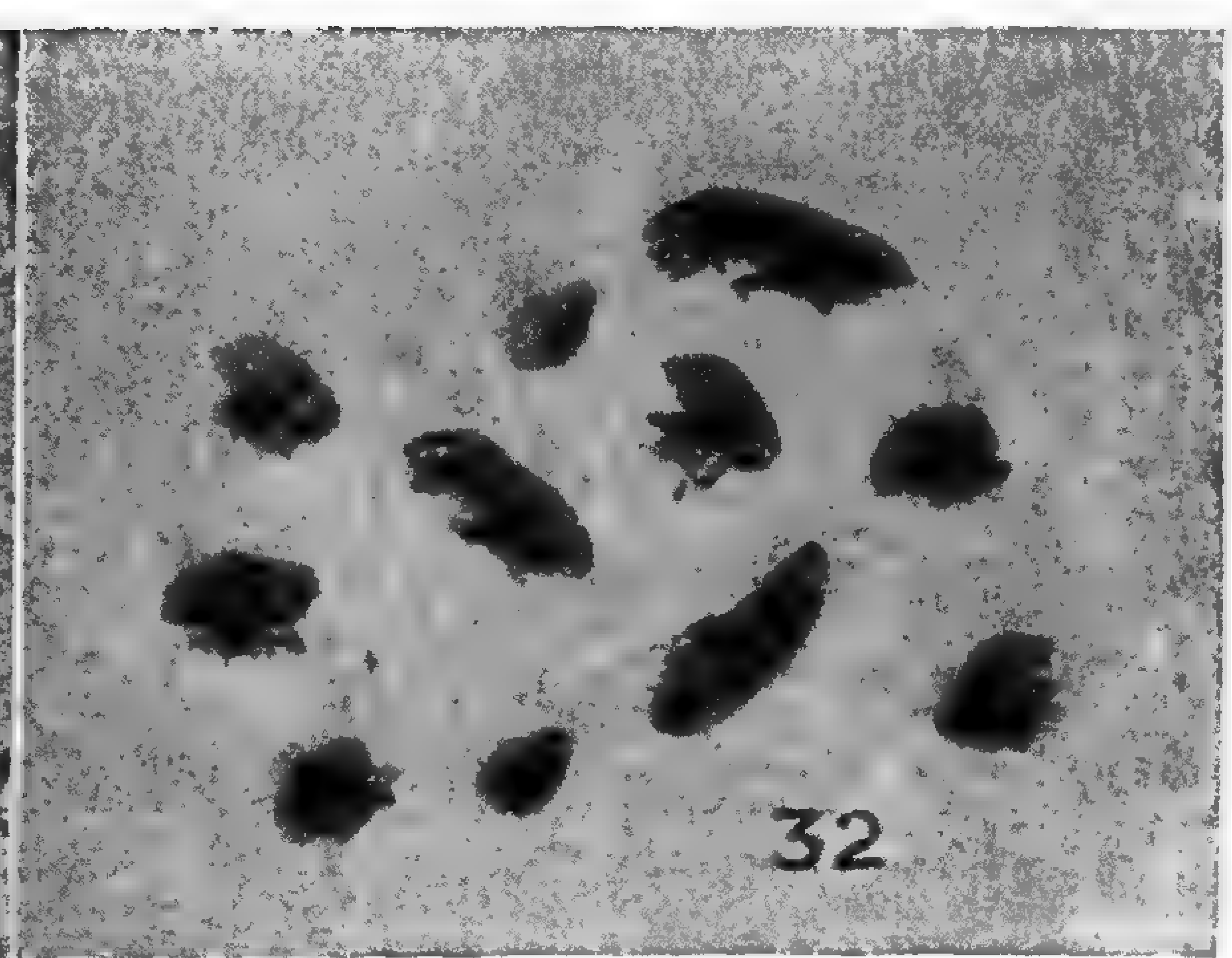

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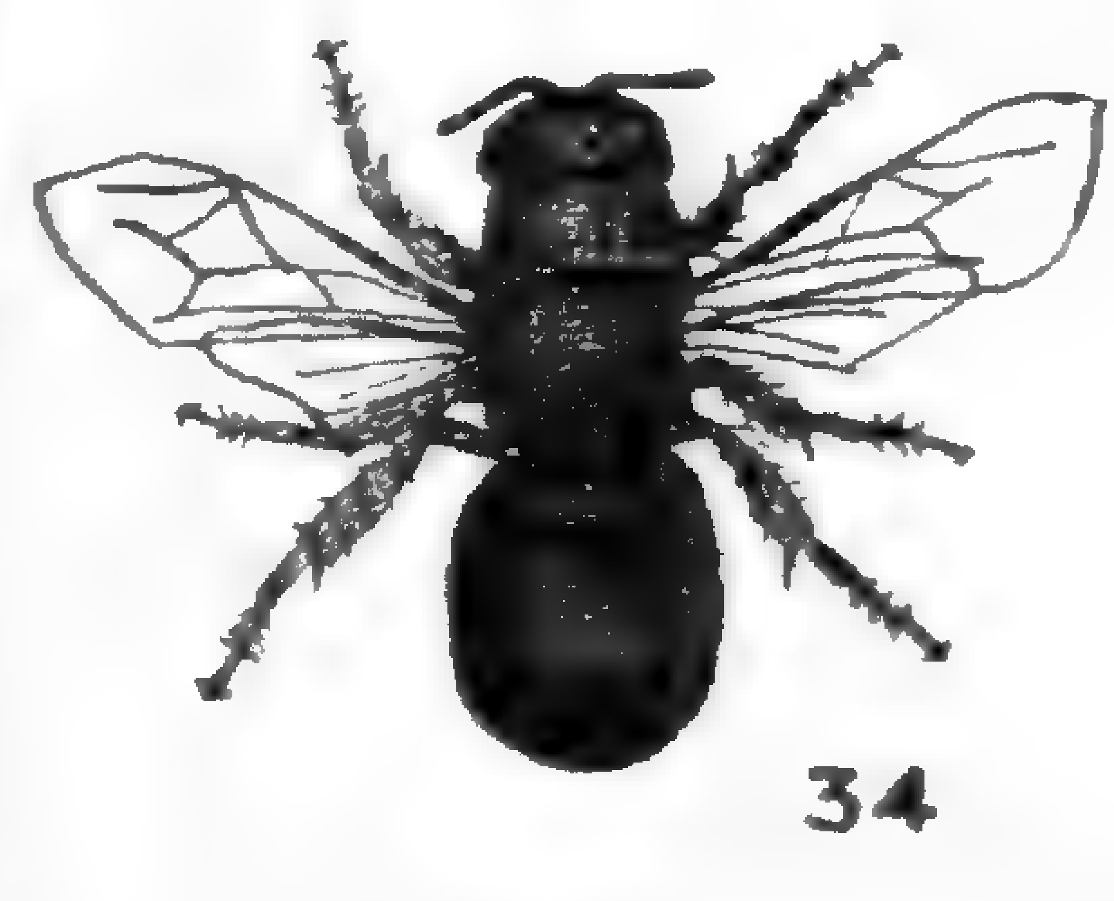

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EXPLANATION OF PLATE

Plate XXIV

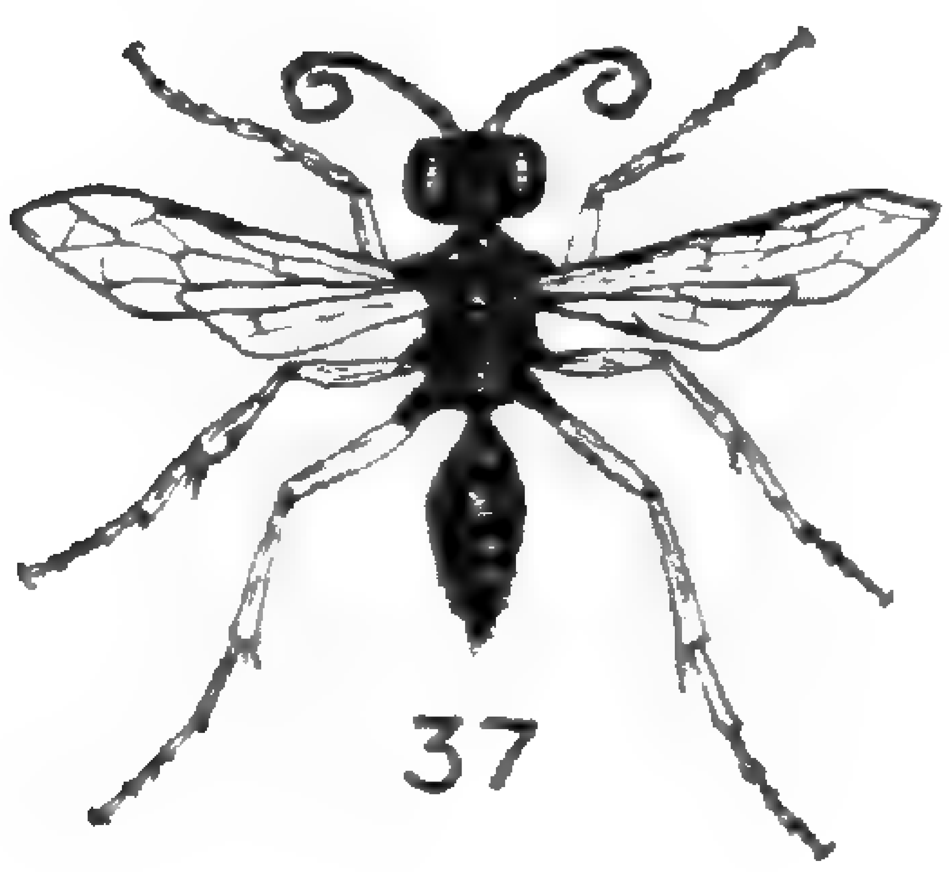
Fig. 35. The entrance to the nest of *Cerceris bicornuta.*

Fig. 36. The burrow of *Bembix nubilipennis,* enlarged by *Cerceris bicornuta.*

Fig. 37. *Pseudagenia mellipes.*

Fig. 38. The wall removed from nests of *Sceliphron caementarium* to show (arrows) the nests of *Pseudagenia mellipes.*

Fig. 39. Interior arrangement of cells of *Pseudagenia mellipes* in nest of *Sceliphron caementarium.*



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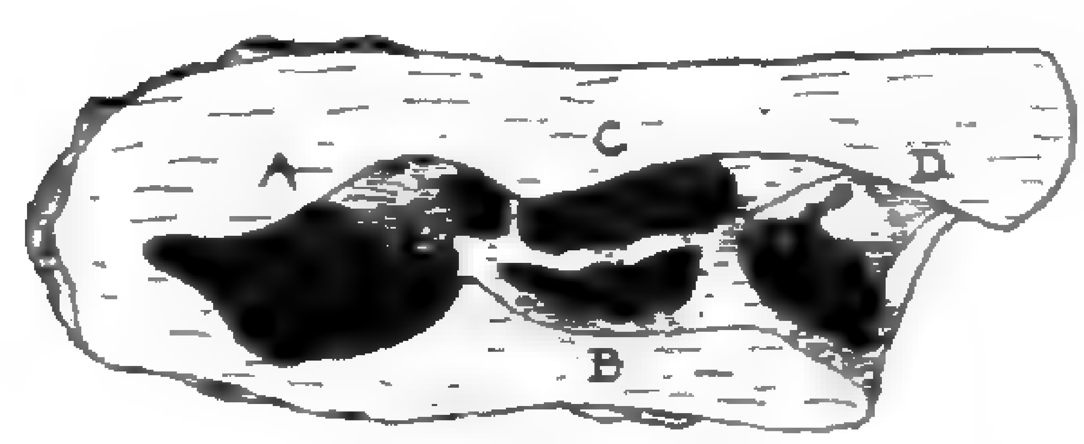

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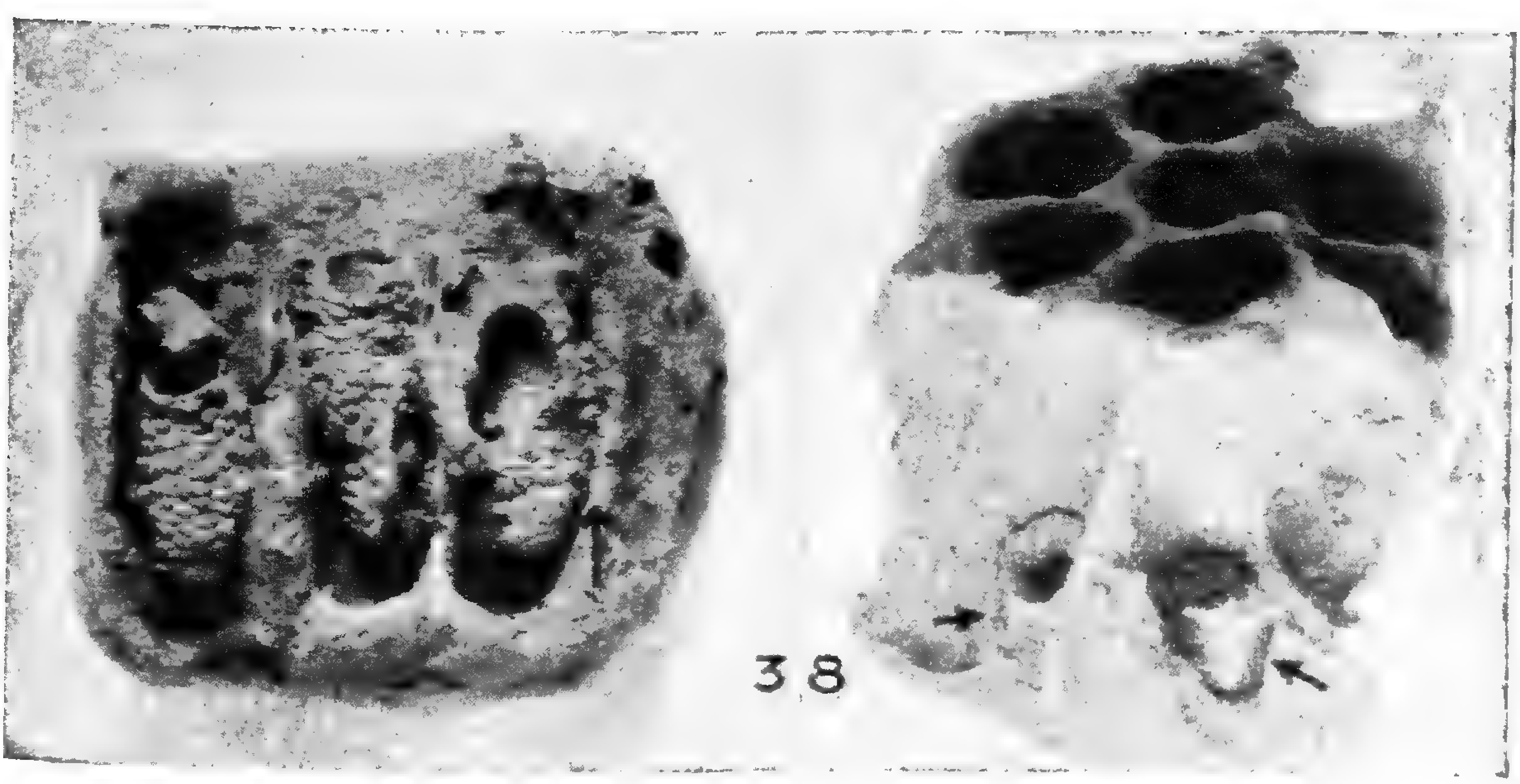

EXPLANATION OF PLATE

Plate XXV

Fig. 40. The cells of *Pseudagenia mellipes* under loose bark.

Fig. 41. The burrow of *Xylocopa virginica* and its later tenants.

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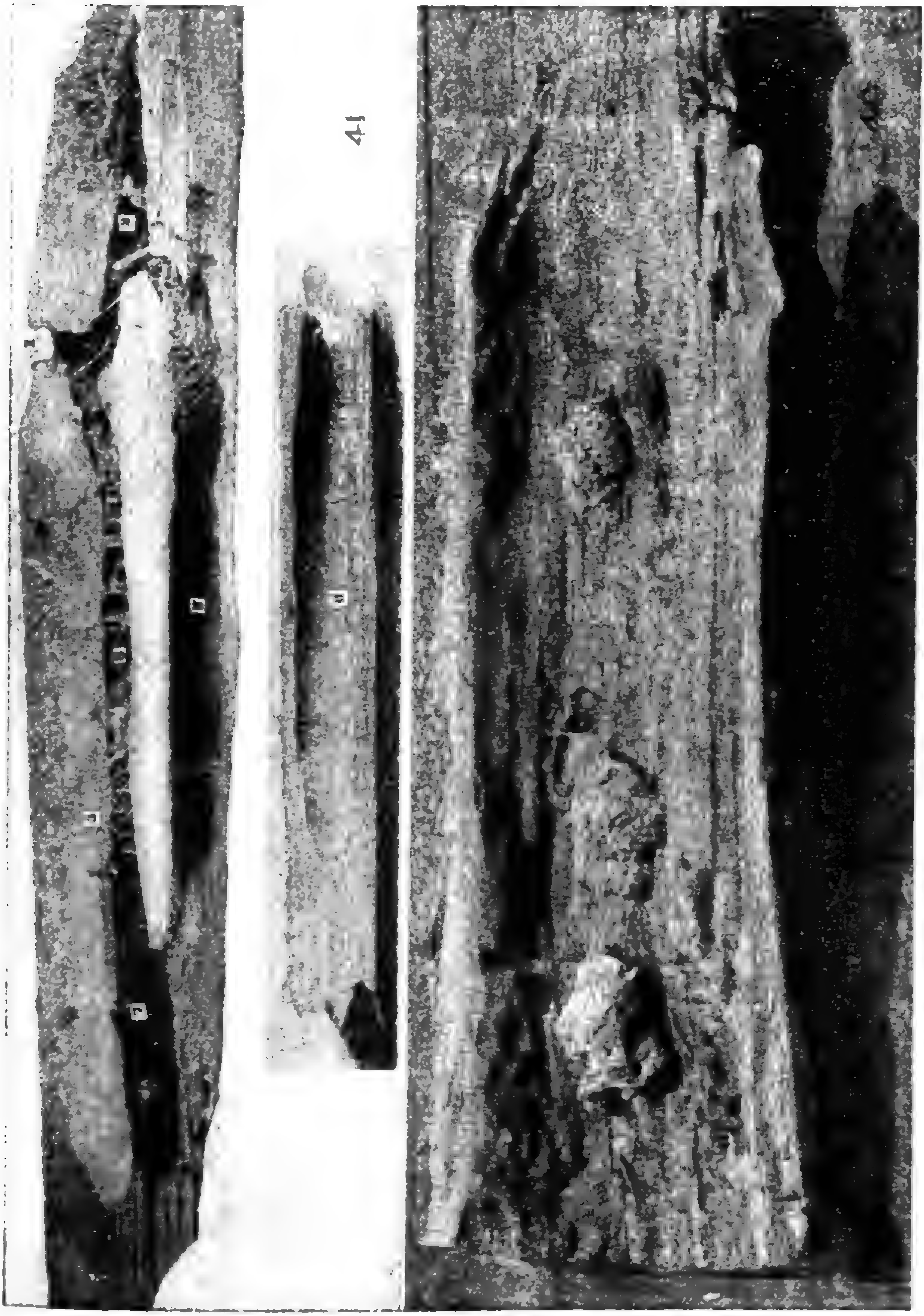

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EXPLANATION OF PLATE

Plate XXVI

Fig. 42. The naked larvae of *Monobia quadridens*.

Fig. 43. The way *Chlorion auripes* plugs her nest with grass.

Fig. 44. The nests (A, B, C) of *Chlorion auripes* in elder stems, (D) the grass plug in burrow of a mining bee.

Fig. 45. *Chlorion auripes* and its prey, *Oecanthus latipennis*.

Fig. 46. *Diphlebus bipartior* (two and one-half times natural size).

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EXPLANATION OF PLATE

Plate XXVII

Fig. 47. The nest of *Diphlebus bipartior* (one-third natural size).

Fig. 48. *Silaon niger* (two times natural size).

Fig. 49. Cocoons of *Silaon niger* in a twig formerly used by *Hypocrabro stirpicola.*

Fig. 50. The tunnel of *Hypocrabro stirpicola* showing (P) the fine pith for partitions and the big rough bits (F) for filling the empty gallery. (C) is one of the cocoons.

Fig. 51. The nest of *Odynerus leucomelos* (natural size).

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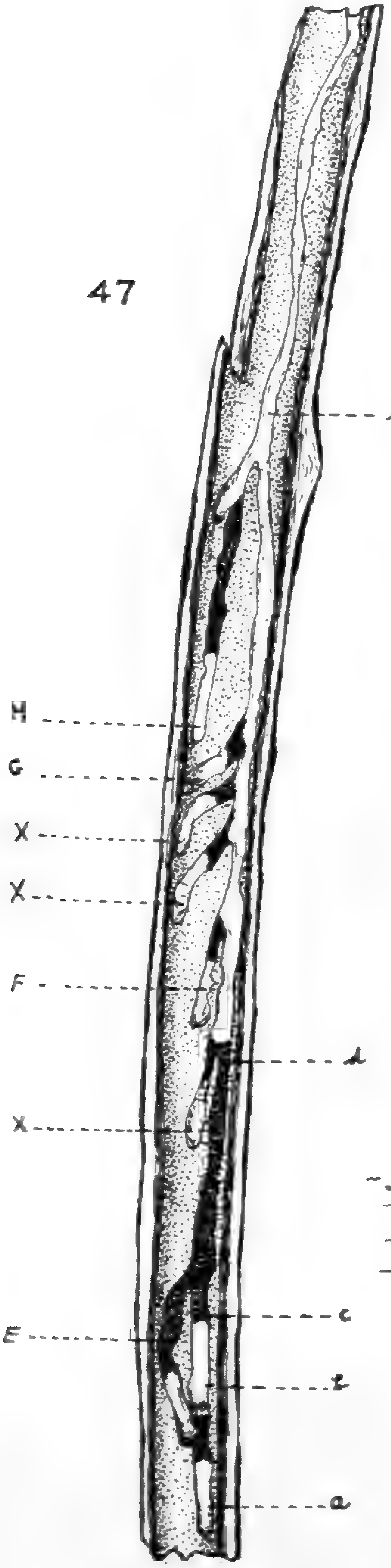

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EXPLANATION OF PLATE

Plate XXVIII

Fig. 52. The burrows of Stenodynerus zendaloides. (P) pith, (C) mud cocoon. (S) empty space.

Fig. 53. *Trypoxylon clavatum.*

Fig. 54. The nest of *Seeliphron carmentarium* re-used by *Trypoxylon clavatum.* (A) contains the cocoons and debris, (B) has them removed to show the well-made partitions.

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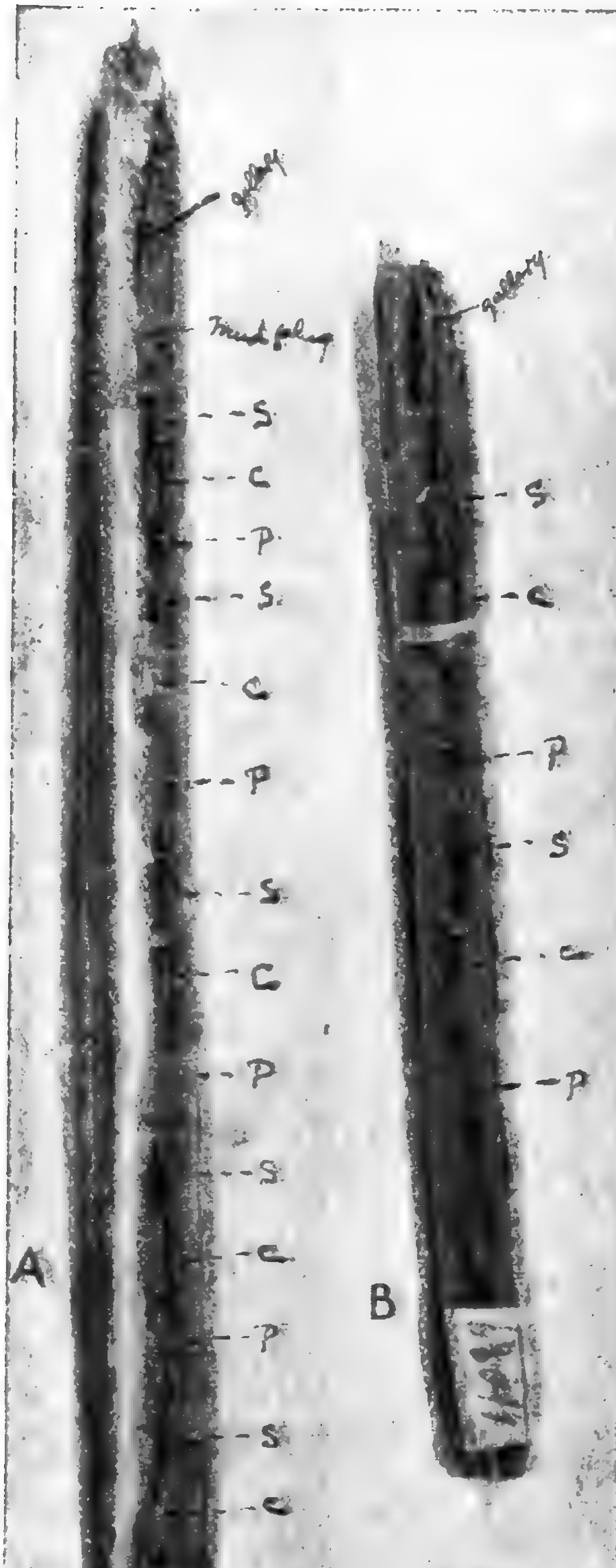

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EXPLANATION OF PLATE

Plate XXIX

Fig. 55. The nests of *Trypoxylon clavatum* in the bank; (X) air chambers.

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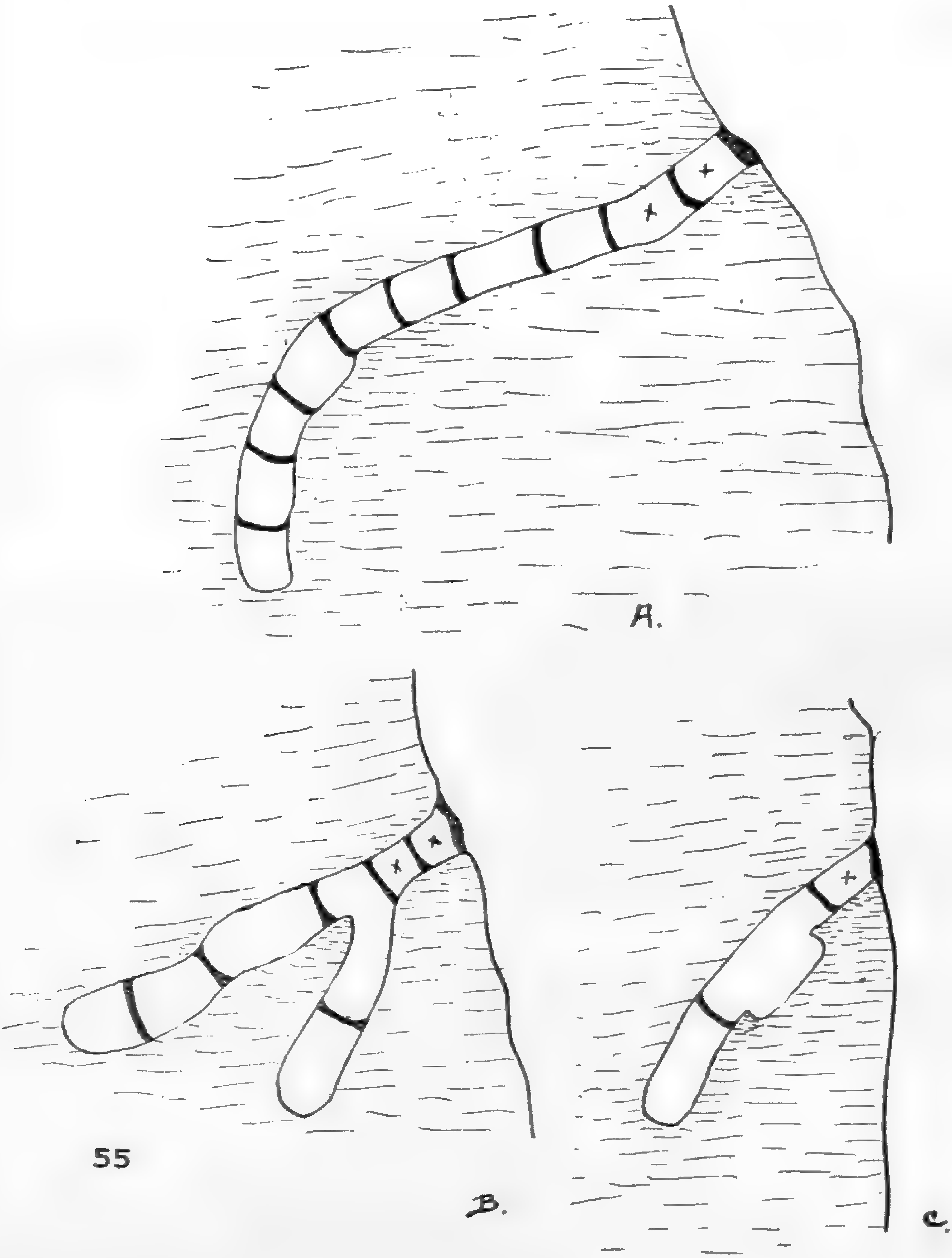

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EXPLANATION OF PLATE

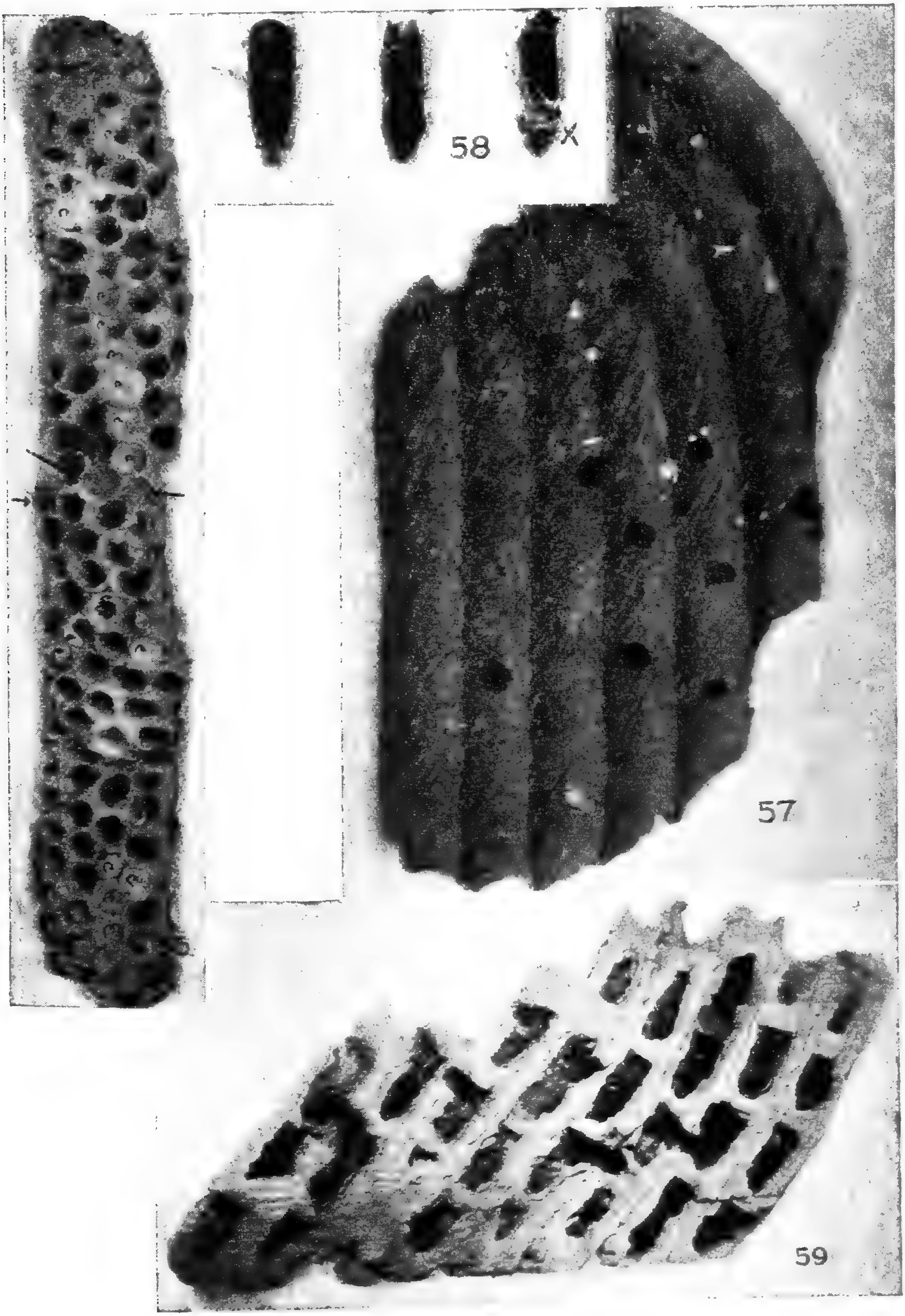
Plate XXX

Fig. 56. An old nest of *Polistes pallipes*, used and re-sealed with mud (C) by *Trypoxylon clavatum*, and with wax (arrows) by *Osmia cordata*.

Fig. 57. The pipe-organ nest of *Trypoxylon politum*.

Fig. 58. The cocoons of *Trypoxylon politum*. (X) shows remnant of webby covering.

Fig. 59. Back view of nest of *Trypoxylon politum*.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EXPLANATION OF PLATE

Plate XXXI

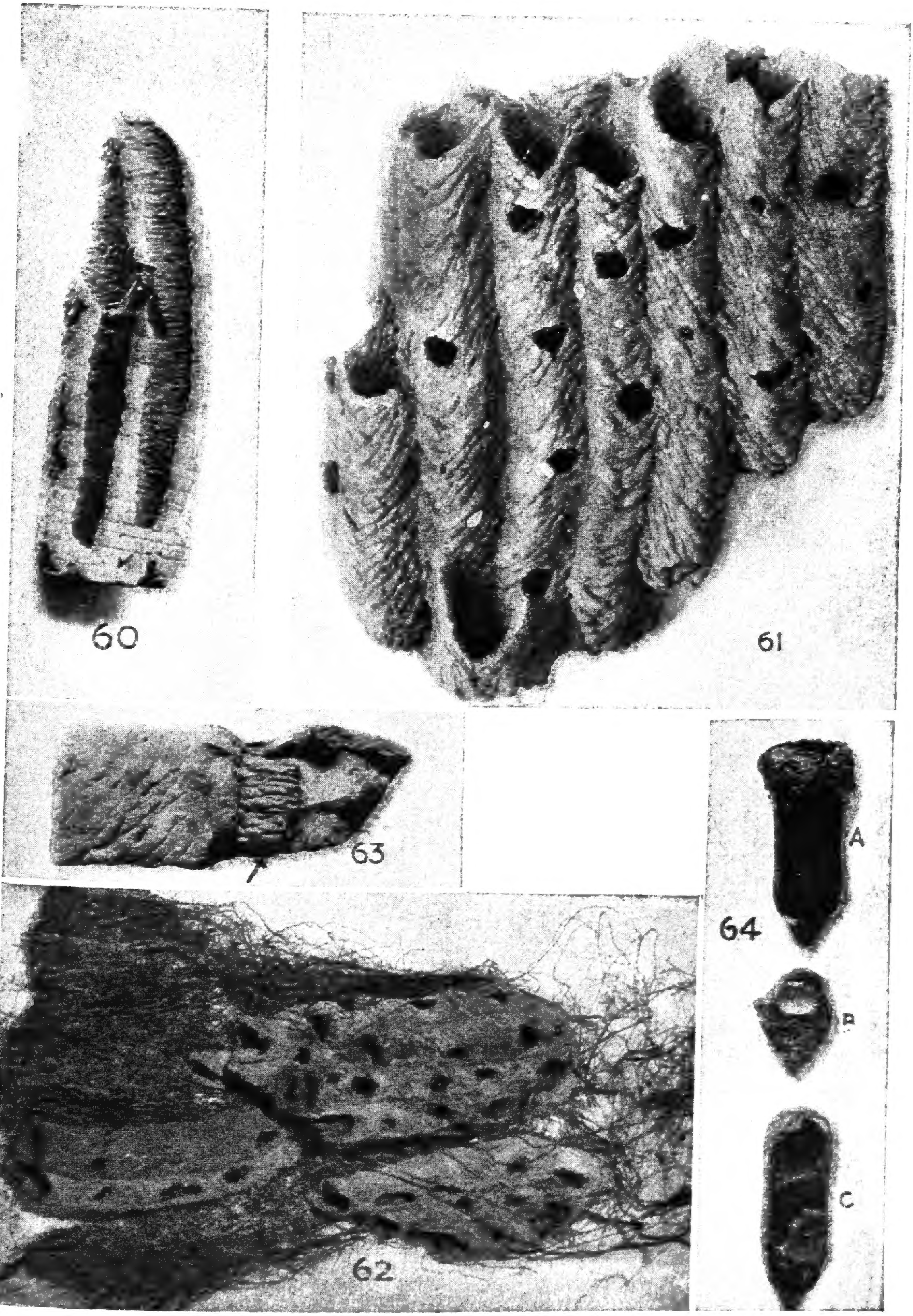
Fig. 60. The long pipes *Trypoxylon politum* are first made and then partitioned into cells.

Fig. 61. A nest of *T. politum* two tiers deep.

Fig. 62. A nest of *T. politum* built on the mat of roots.

Fig. 63. A portion of a nest of *T. politum* broken off to show the thimble-shaped nest of *Pseudagenia mellipes.*

Fig. 64. The cocoons of *T. politum* re-used by *Osmia cordata.* (A) shows the waxy patchwork on top of damaged cocoon, (B) the wax plug with opening made by the emerging *Osmia,* and (C) the waxy portions.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A
B
C

EXPLANATION OF PLATE

Plate XXXII

Fig. 65. The nest of *Trypoxylon plesium.*

Fig. 66. (A) A nest with seven cells of *Trypoxylon plesium.* (B) A twig with the nest of *Trypoxylon plesium,* showing manner in which mica is placed in position to facilitate study.

Fig. 67. A nest of *Sceliphron caementarium* decorated with balls of mud.

Fig. 68. The cocoons of *Trypoxylon texense* in an old nest of *Sceliphron caementarium.*

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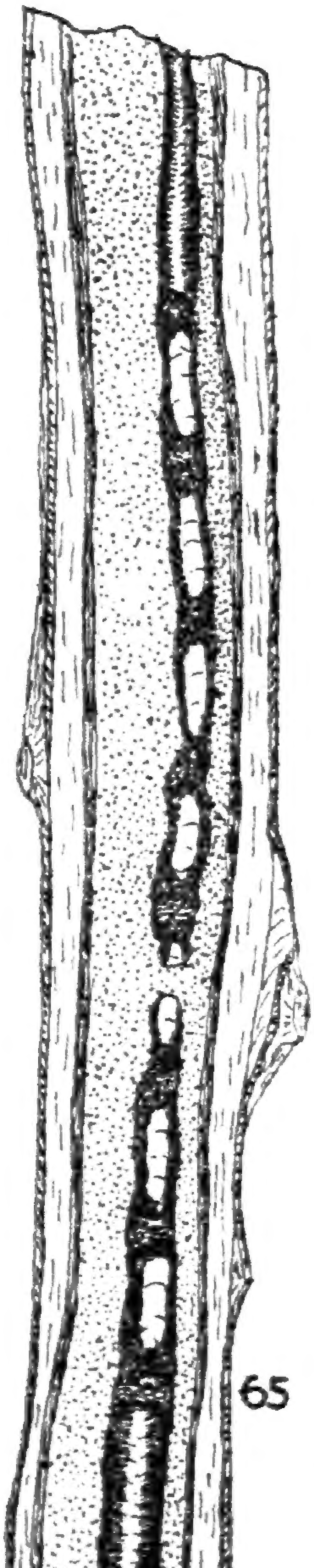

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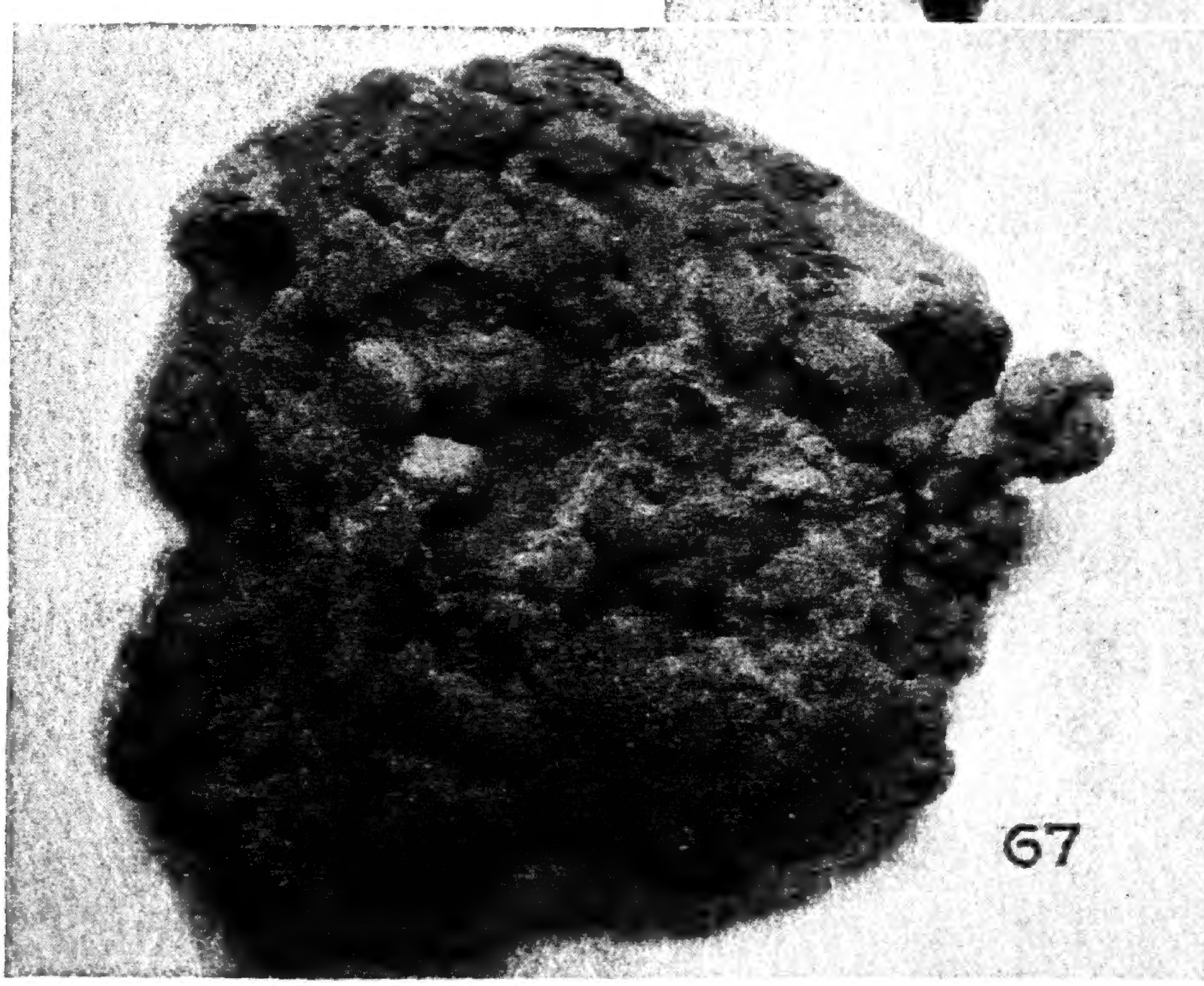

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